MINISTRY OF FINANCE.

SURVEY DEPARTMENT

A PRELIMINARY REPORT

ON THE

GEOLOGY OF THE EASTERN DESERT

OF EGYPT

BETWEEN LATITUDE 22° N. AND 25° N.

BY

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SANDSTONE PLATEAU NEAR THE NILE, WADI ABAD.

EASTERN EDGE OF SANDSTONE PLATEAU, FACING THE SCHIST AREA, WADI BARAMIA.

LIST OF ILLUSTRATIONS

LIST OF MAPS, Scale $\frac{1}{500{,}000}$

BIR SHADLI. WITH TOMB OF SHEIKH IN BACKGROUND

SCHIST-RANGE OF MUXIM, OVERLOOKING GRANITE PLAIN.

INTRODUCTION.

The present report contains a preliminary account of the topography and geology of the Eastern Desert between lat. 22° N. and 25° N. It has been compiled from the field notes of the surveyors and geologists in order to furnish as soon as possible a general account of the district, without waiting for the final results of petrological and other studies which will occupy a considerable time. It may happen therefore that some of the results arrived at in this Preliminary Report may be considerably modified by subsequent field-work and laboratory study.

The topography was commenced in the winter of 1904 when a chain of triangulation was carried from Edfu on the Nile to the shore of the Red Sea, and though this work occupied most of his time, Mr. Villiers Stuart also added a certain amount of topographic detail. In the following season two parties, under Mr. Villiers Stuart and Dr. Ball respectively, extended this line southwards approximately along the 34° 15′ E. and 34° 45′ E. meridians, the former being carried southwards as far as lat. 22° N. and then joined to the Nile Valley triangulation in lat. 23° 10′ N. while the latter (Eastern) chain was carried down to lat. 24° N. In addition the members of the Geological Survey (see p. 9) carried out as much topographical and geological work as was possible in the time available.

The increase of mining operations in this portion of the desert has necessitated the accurate determination of a number of points by triangulation from which concessions and leased areas could be located. This work was carried out by means of 6-inch micrometer theodolites, and was connected to the Second Order Triangulation of Egypt at Edfu, Kom Ombo and Dakka. Three control base-lines were measured which established that the accuracy of the work was well maintained and of a much higher order than was absolutely necessary for locating mining claims. It is, however, of very considerable value in controlling the topography of the western coast of the Red Sea, and the additional

cost of the higher class work is extremely small since transport and delays of travel account for by far the greater portion of the expenditure in time and money.

A measure of the accuracy of the work may be got in the closing differences at Kom Ombo and Dakka. At the former the differences of latitude and longitude when computed through the Desert and Valley triangulation were 0″.15 and 1″.9 respectively, while at Dakka the corresponding quantities were 1″.3 and 0″.5. This gives every confidence in the accuracy of the triangulation. As the result of connecting the western shore of the Red Sea with the Nile Valley through a chain of nine quadrilateral figures, an improved value has been obtained for the longitude of this coast-line. Taking the point Mersa Imbarak, its position is found to be as given in the following table:

	Survey	Admiralty Chart	Red Sea Pilot
Latitude..	25°. 30′. 42″	25°. 31′. 18″	25° 30′. 0″.
Longitude	34°. 38′. 52″	34°. 36′. 24″	——

In the following table is given a list of the points determined by triangulation, which have a definite name and can therefore be readily recognized in the field:

Place	Latitude			Longitude			Altitude
							m.
G. Um Negat	25	29	42	34	13	58	1310
G. Beda	25	27	46	33	41	26	..
G. Hadalawi	25	27	0	34	1	21	..
G. Kodoboro	25	26	40	34	26	49	850
Wadi Maiyit (cairn).	25	16	29	34	8	0	..
G. Um Sumra South.	25	14	2	34	7	49	900
G. el Anga or Annegi	25	13	17	34	8	4	990
G. Abu Diab	25	12	12	34	13	41	1160
Cairn above Bir Beza	25	10	46	34	4	42	..
G. Hamaret Wogud..	25	9	34	34	20	0	1103

Place	Latitude			Longitude			Altitude
							m.
G. Um Sellim or Um Salatit . ..	25	8	26	33	51	33	..
G. Iteima or Itami	25	8	1	34	11	13	849
G. Igli Atshani..	25	6	35	34	41	46	..
G. Igli	25	4	55	34	35	29	..
Baramia	25	4	17	33	47	04	..
G. Igli el Iswid.	25	4	6	34	36	16	975
G. Atut	25	0	56	34	23	49	908
G. Abu Marwa	25	0	28	33	56	44	..
Erf el Fahid	25	0	5	34	11	52	579
G. Hagar Dungash	24	59	12	34	2	33	815
G. Sukkari	24	56	50	34	42	56	476
Dungash	24	56	6	33	52	52	..
G. Um Tundeba	24	55	43	34	47	35	550
G. Muelih	24	52	44	34	0	37	707
G. Kurdeman	24	52	31	34	41	38	526
Marwot Rod el Ligah	24	51	31	34	8	21	514
G. Mudergeg or Muderdagat.. ..	24	51	5	34	21	59	885
G. Ghadir	24	50	9	34	47	22	636
G. Nugrus	24	48	34	34	35	47	1505
G. Migif	24	47	23	34	27	30	1199
G. Allawi	24	46	42	34	49	39	515
G. Zubara	24	45	16	34	41	46	1361
G. Lewewi..	24	44	35	34	46	35	654
G. Abu Khrug	24	38	57	34	16	19	870
G. Sikait	24	39	55	34	48	5	771
G. Sufra	24	38	42	34	4	13	690
G. Nahud (north)	24	35	48	34	22	9	..

Place	Latitude			Longitude			Altitude
G. Hafafit	24	35	32	34	45	22	744
Madaret Um Gamil	24	34	52	34	56	28	454
G. Abu Had	24	34	2	34	36	9	633
G. Nahud (south)	24	33	42	34	20	11	..
G. Um Regeba	24	33	30	34	42	36	571
G. Um Sueh	24	26	55	34	54	28	781
G. Um Suerab	24	26	50	34	42	40	1024
G. el Heda	24	20	55	34	30	10	862
G. Um el Abbas	24	26	18	34	56	39	697
G. Abu Heglig	24	26	16	34	58	32	607
G. Nukheira	24	25	45	34	33	2	876
G. Um Goraf	24	25	33	34	18	28	..
G. Durunkat	24	23	47	34	46	0	924
G. Um Sedri	24	21	42	34	41	10	970
G. Um Heshenib	24	20	49	34	50	53	1135
G. Muktil	24	20	28	34	2	18	..
G. Khulla	24	19	47	34	38	46	978
G. Tarfawi	24	18	49	34	56	0	1363
G. Marasan	24	17	40	34	45	5	1261
G. Mitawit	24	15	48	34	31	45	741
G. Abu Hamamid	24	14	41	34	47	38	1747
G. Um Usher	24	14	13	34	53	28	1487
G. Um Hasidok	24	12	47	34	54	44	1497
G. Hamata	24	12	17	35	0	16	1978
G. Homr Akarim	24	11	45	34	4	0	..
G. Abarun	24	11	20	34	50	18	1602
G. Abu Argub	24	11	1	34	45	39	1609

Place	Latitude			Longitude			Altitude
G. Hamrat Mukbud..	24	9	53	34	23	17	..
G. Ras el Kharit	24	9	23	35	1	57	1661
G. Khashir	24	9	23	35	4	46	1565
G. Kahfa	24	8	18	34	38	51	1018
G. Mikbi	24	4	52	35	4	46	1388
G. Egat	24	2	50	35	2	29	1422
G. el Ghar	24	2	40	34	14	4	..
G. Abu Gurdi	24	0	11	35	5	17	1562
G. Um Gunud	23	57	45	35	12	12	989
Erf el Mohaïb	23	56	23	34	8	50	465
Marwot Elemikan	23	54	10	35	6	10	648
G. el Nekib.	23	52	34	34	22	10	570
G. Feleiti	23	48	32	34	13	46	..
G. Um Harba	23	36	55	34	30	38	688
G. Mulgata	23	36	9	34	12	43	545
G. Narg'	23	30	43	33	48	22	..
G. Feraid (The Bodkin)..	23	28	57	35	20	34	1232
G. Ziraga	23	26	58	34	15	33	553
G. Owamtib.	23	20	59	34	26	39	793
G. Mowisat.	23	17	26	34	15	48	..
G. Beid el Kalb	23	16	35	33	48	58	..
G. Etrisia	23	9	29	34	30	35	1037
G. Nosair	23	7	20	33	48	32	..
G. Abu Rihaiya	23	7	4	34	4	14	835
G. Hamrat Feg..	23	4	31	34	19	47	..
G. Um Tamam..	23	1	33	33	37	11	..
G. Nusub Zrar	22	58	56	33	13	55	..

Place	Latitude			Longitude			Altitude
G. Um Amka	22	58	12	33	28	35	..
G. Haserba	22	56	25	33	30	58	..
G. Hemmara	22	56	22	33	21	13	..
G. Um Tanedba	22	56	10	33	53	54	900
G. Handalit.	22	51	39	34	13	49	..
G. Absiel	22	49	3	33	42	6	..
G. Denabt el Qolaib..	22	43	58	33	25	37	..
G. Seiga	22	43	31	34	16	16	905
G. Ribdab	22	41	53	33	59	52	..
G. Nusb Allowba	22	40	1	33	55	37	..
G. Um Krush	22	38	15	34	5	21	..
G. Dehais	22	36	41	34	0	16	..
G. Um Garaiart	22	33	20	33	23	4	..
G. Um Rilan	22	31	51	33	38	42	..
G. Muqsim..	22	10	11	34	1	12	825
G. Ongat	22	6	35	33	46	26	..
G. Abu Dom	22	1	16	34	15	40	..

PART I.

GENERAL TOPOGRAPHY.

The district under review is that portion of the Eastern Desert which lies between latitudes 22° and 25° N. and extends from the Nile, between Edfu on the north and Alagi on the south, to the western shore of the Red Sea. It divides itself naturally into three areas, the sandstone country forming the western portion, the centre being more a region of isolated hill masses and broad plains, while to the east, behind the central watershed ranges, extends a complicated country, where deep and close-set valleys are separated from one another by arid mountains with precipitous and rugged sides. This eastern portion has been triangulated by Dr. J. Ball, who in addition made a topographical map of the country traversed, and such geological observations as were possible in the time at his disposal. Most of the important peaks in this district were ascended as stations, including such heights as Hamata (1978 m.), Abu Hamamid (1747 m.), Nugrus (1505 m.) and Sikait (771 m.). The detail mapping was done by plane table with telemetric alidade. The season's work terminated a little south of latitude 24° N.

In the central portion the triangulation was entrusted to Mr. Villiers Stuart, who also did as much topography as was possible in the time at his disposal. Mr. P.C.A. Stewart was associated with him, having under his special charge the geological and topographical work of the expedition. Owing to the rapidity of movement rendered necessary to complete the triangulation to latitude 22°, the record was obtained by prismatic compass traverse, based on camel-rate, and checked by plane table station observations at least once every day.

In the western region, Mr. H. T. Ferrar, in a series of flying traverses, mapped the main valleys descending through the sandstone area, and covered about 24,000 square kilometres. For this purpose he connected with the Nile and Central Desert triangulation whenever possible. Finally, the writer visited each party in turn, collecting specimens and geological notes, the general results of which, together with those obtained by the other field-workers, are embodied in the following remarks.

TOPOGRAPHY OF WESTERN AREA.

The essential feature of the region forming the western half of this desert is the fundamental plateau structure due to the presence of the Nubian sandstone (See plate I). A closer examination shows that the plateau has been profoundly eroded, the valleys descending from the Red Sea hills cutting through it in deep ravines. It is possible that there are structures of deeper significance as well, which require further examination; thus Ferrar has called attention to a great NW.–SE. *trench* in the Nubian sandstone from Wadi Baramia to Wadi Kharit. The sandstone region as a whole has at its eastern limitation a scarp which faces the country occupied by the igneous and metamorphic rocks. This steep scarp normally trends uniformly NW.-SE., though, as will be seen from the map, volcanic rocks and faults have disturbed its regular arrangement.

TOPOGRAPHY OF CENTRAL AREA.

Lying to the east of the sandstone scarp is a region in which great plains or low hill-country are very marked features, and out of which rise sharp-pointed peaks or long ridges, such as Abu Khrug, Hamret Mukbud, and El Silaia in the north, or Muqsim, Abu Brush and Ribdab in the south. Between latitudes 22° N. and 22° 30′ N. plains are still an important feature to the west of the watershed; to the east of it, however, are several important ranges. Nothing can be imagined more desolate than the vast plains of Shigig, where not a blade of vegetation brightens the sun-burnt and sand-strewn desert.

TOPOGRAPHY OF EASTERN AREA.

Between latitudes 24° and 25° N. the watershed for a part of its course follows a high mountain wall (see map); turning west over Nugrus and Migif it leaves the hill country and crosses a high level plain, but again rises in the hills to the south-west of Wadi Huluz, and attains its maximum height of 1747m. in Gebel Abu Hamamid. Thence it continues in mountainous country south-east to Gebel Ras el Kharit (1661m.), whence it passes a little east of south, still in high country, via Gebels Mikbi and Egat, to Gebel Abu Gurdi (1562m.). South of Abu Gurdi it descends into lower ground, but its further course has not yet been traced.*

* If the guide's statements as to the watershed are confirmed, from this point it takes a great bend westward. The writer has personally little doubt that this is the case, but it requires confirmation by accurate survey, and the matter is now receiving attention.

The eastern region is, as above stated, remarkably complex in its structure. In the centre towers the commanding mass of mountains of which Hamata is the chief. To the north the less elevated hills of Um el Abbas nevertheless attract attention by the precipitous character of their cliff faces and the rounded nature of the summits. Still further to the north the hill-structure becomes intensely complex in the neighbourhood of Sikait, though the parallel ridge of Hafafit and the straight valley of Nugrus show that regular features are not entirely absent. This is essentially a land of precipice, of rugged scarp, of deeply scored mountain side, but in its broader valleys it is the home of vegetation and of life. Communication from transverse valley to valley is not always easy, steep passes making it difficult to move from north to south.

To the east of Hamata the central range dominates a low granite country traversed by wide valleys, and the impression left on the mind is that of comparatively rich vegetation and cheerful surroundings, very different from the sand-drifted monotony of the central portion of the desert. The area has hitherto been little studied and our knowledge of it at present depends on the following published maps and descriptions; Linant de Bellefonds, who specially visited Hegatt and Daraheib, *L'Etbaye*, Paris (undated, but about 1854) ; Floyer, *Étude sur le Nord Etbai*, le Caire, 1893 ; Purdy, *Reconnaissance entre Berenice et Berber*, Bull. Soc. Khéd. Geog., II Ser., No. 8, pp. 431-447 ; Colston, *Journal d'un voyage du Caire à Keneh, etc.*, Bull. Soc. Khéd. Geog., II Ser., No. 9, pp. 489 - 568 ; and in the Um Garaiart area the map of the Nile Valley Company. Various smaller sketch maps have been made but have not been published, or have appeared only in the reports of mining companies. Among these we may refer to Mr. James' traverses in the Streeter concession, and Mr. Donal's record of the Dungash-Sammut road. The Inspector-General of Mines also kindly placed at our service the observations and notes* he had made during his traverses in the northern portion of this region, and in 1902 had presented a report on the Um Garaiart concesssion (with a geological map made by Mr. Carey) to the Nile Valley C°.

Roads.—The map sufficiently shows the main lines of communication, there being but few passes across the central watershed for a great part of its length. The roads mainly follow the great wadis, most of which are practicable for camels except near their heads.

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* Where not otherwise stated, special notes so used are marked by the initials J.W.

Wells.—The importance of wells in this country need not be emphasized. The mining settlements of Baramia and Dungash possess good wells in their immediate vicinity, the water of Baramia being better than that of Dungash.

Of the desert wells near Edfu, Bir Abad*, on the road to Baramia, is the most important, but the little well of Um Tundeba in the sandstone to the north, made known to us by Green, is also of interest. In the next great drainage-channel to the south, Wadi Shait, there are several wells. In the sandstone region, the galt (or waterpool) of Um Sellim was dry in November, 1905, though Macalister found it full after a rainy season, and ten kilometres to the south of this the well of Wadi Legaia has been recorded by several travellers.

In two of the northern tributaries, Wadis Sammut and Sibrit, there are important wells, the water of the latter being especially good and abundant in December, 1905, but it has but little water now.

There is, on the other hand, a fine supply of water in the westernmost shaft of Hamish mine, and Sammut still gives a fair supply.

Returning to Wadi Shait itself, there is a dry well at the edge of the sandstone, Bir Heliwat, and, on issuing from the sandstone, Bir Um Gubur is found a few kilometres to the east. From this well the water trickles in as fast as it is removed, if taken in small quantities. Still further to the east is the very unpleasant well of Um Murra, the last supply in Wadi Shait before the waterpools of Migif are reached.

Between Wadis Shait and Kharit the district is exceptionally waterless so far as our experience goes, though near Wadi Natash is the Masur well, hidden in a small wadi near Gorf el Natash hill with but little water at present in it. Further south there are several wells in the small valleys which drain from the Gebel Hamamid area towards Wadi Kharit. Among these is a deep one in Wadi Ghashab, empty at the time of our visit; another is in Wadi Metawit and yet two others in Wadi Abu Hamamid, which are known as the Abu Hamamid wells. One of these was destroyed last year by a rainstorm, but has since been re-opened. Of most general interest is the pool of El Shadli (see plate II). This spot is one of the principal holy places in the Ababda country, a large tomb having been built here in memory of Sheikh Shadli, who is said to have been one of the chief followers of Mohammed. Here year after year, the head Sheikh is present for one of the principal festivals, tribesmen assembling from all parts to celebrate the occasion. The water of the pool is variable in character, being of good

* To this must be added the Mines Department well at Kanais (the old Egyptian temple in Wadi Mia), which now yields a continuous water supply.

quality in winter after the fall of rains in the ranges to the east, but becoming unpleasantly salt in summer or during rainless periods. * This is true also for most of the desert wells. About four hours SW. of Shadli is another well, Bir Helie, of excellent water, which the Ababda are not particularly anxious to show. Passing for a moment to the eastern side of the watershed, the extent of supply depends to a large extent on the direct rainfall, as much of the water occurs in waterpools in the upper mountain valleys. Naturally the most abundant sources are to be found in the recesses of the central range, and among these the most important are the pools of Wadi Ghuel, Zubara and the head of Wadi Nugrus.

In the lower hills to the east is another excellent pool up a small side ravine of Wadi Um Tundeba (see map). This is in a very picturesque situation, the brilliant colouration of the dykes which form the walls of the gorge contrasting well with the deep green water at its foot. Further to the south in Wadi Ghadir is an artificially constructed well which had been filled up at the time of our visit, but which, from the information given, is of great importance during the summer months or rainless years. We were also informed that there is a well on the sea-shore at the mouth of Wadi Ghadir, into which the water trickles as fast as it is removed. At the Sikait mine a well has been dug in the main valley, but the water is of poor quality. There is, however, at the head of one of the small valleys to the northward a "megal" or spring, which daily yielded small quantities of excellent water, and is treasured with special care on this account. The previous expedition as described by Macalister † was particularly fortunate in visiting the spot just after a heavy rainfall, and in consequence he was enabled to refer to several waterpools which at the present time are empty. Further south, mention may be made of the fine waterpool in Wadi Um Gerifat, close to Wadi Huluz, while by a general concensus of opinion the Hamata range may be considered as one of the best water centres of the country. In the flying trip which the writer took on the eastern side of that range the water difficulty never became acute.

The chief sources of supply were in Wadi Abu Khalga, west of Gebel el Ranga, which was not visited, and on the shore at El Ranga

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* The variability in size and quality is illustrated by the fact that at present (November, 1906), Dr Ball reports the pool to be at least 3 metres lower than in December, 1905, when the writer visited it. "It is in fact a miserable little water hole about ½ metre in diameter, and the well of Abu Hamamid is far more important, this being the best of the old wells at present." For his notes on the present condition of other wells, see above.

† "Geog. Jour." 1900, p. 537.

there is a brackish well which need only be used in case of urgent necessity.

In the next valley to the south is Bir El Gulan, whose supplies are variable, and it is advisable to ascertain if possible what is the condition of this well beforehand, as otherwise in rainless seasons serious difficulty may be encountered with regard to the supply of water. There is, however, in this neighbourhood a very important source of water at the spring of Amar. This spring is hidden away in the low hills south of Hamata, and unless revealed by the guide would not be easily found even by an observant traveller, for there are no definite tracks leading to it and the country in front is a complex of low hills.

Sufficient has been said to show that in the eastern portion of the desert the water supply, if not excessive, is in general adequate to the needs of travellers, but in this matter much depends on the character of the guide accompanying the expedition, and on the confidence which the traveller is able to instil into the men accompanying him, for there is always a not unnatural desire to withhold information as to wells and pools on which the desert-dweller is himself largely dependent.

Returning to the west of the watershed, a very important group of water holes has next to be mentioned. The first of these is the one noted by Dr. Ball about $1\frac{1}{2}$ km. SE. of Gebel El Selaia, which he reports as containing excellent water, though the supply is apparently a limited one. Further east, on the other side of the watershed in one of the heads of Wadi Lahami is a large pool called Galt Um Gunud. This is shown on the map in the position pointed out to Dr. Ball by the Arab guides from the top of Gebel Abu Gurdi. Dr. Ball did not himself visit the place, but his Arabs brought supplies of excellent water from it.

Further to the south-west of the Lahami pass is the well of Abu Beid, situated in a pretty valley which contains many seyal trees, and supplying a fair quantity of good water at the time of visit. But of all the sources of water in this neighbourhood, undoubtedly the most valuable and necessary are those connected with the eastern edge of the Nubian sandstone, such as the Abrak and Abu Saafa springs.

The Abrak sources are three in number, the more northern being a pool situated at the foot of a sandstone scarp in the shade of a grove of Seyal acacias. The southern one is situated up a small valley filled with blocks tumbled from the sandstone cliffs above. Here, in recesses beneath the shade of two or three giant boulders, are limpid pools of pure water, and so far as could be seen this was in large quantity, though the source of supply is hidden beneath the stone.

A little further south are other pools which were not examined, while on turning west through a break in the sandstone hills to Wadi Hodein, one of the most beautiful oases in this portion of the desert is reached. Abu Saafa spring owes its origin to the presence of a syncline in the sandstone, the water flowing down the dip-slopes of the massive beds, and escaping in a trickling stream to pools of artificial origin. Purdy has called attention to this well and to the Greek cornice carved in the rocks above it, while he believes the four holes underneath were used for the supports of a roof protecting the water from the sun's rays. At the present day the pools are surrounded by a grove of seyal and palm trees, behind which rise the stern precipices of sandstone, giving shelter to a large colony of partridges. The water is of the purest character, and with Abrak this spring constitutes one of the most important sources of water supply in this portion of the desert. This was already realized in the time of the Ptolemies, a large fort having been built at Abrak, while in quite recent days the Ababda held these wells, as well as the one at Haimur, against the inroads of the dervishes. Further references to the historical questions connected with the above will be found in Floyer's work. *

Further up Wadi Hodein (here named Wadi Um Reit) is a deep well dug in the centre of the valley at the foot of a large tree. It yields a supply of mediocre character. It would, however, be of great importance to anyone crossing the desert by the road from Aswan to Wadi Hodein.

To the south-west of this region water appears to be particularly scarce in the central portion of the desert, and beyond the wells mentioned by Purdy and Colston, the country in this respect is largely unknown. †

The well of Um Hebal, situated at the foot of a high precipitous cliff about 40 kilometres S. S. E. of Aswan, is a natural starting point from the western side for the research of the desert south-east of that town, the point aimed for being the Haimur well to be subsequently described. The character of the direct road from Um Hebal to Um Garaiart is well known, as it was not infrequently used by the engineers going to that mine when they traversed the desert. The usual road to Um Garaiart

* " Etude sur le Nord-Etbai," le Caire, 1893, p. 7.

† As a result of his inspection tour in 1904, the Inspector-General of Mines informs me that in the area between Wadi Lahami and Abrak are wells at Betaan (also visited by Colston) which yield excellent water; there is also Bir Rahaba to the east of Abu Daha in Wadi Rahaba and also the well of Muggia on the south of Daha, the latter being rather salt. The considerable information we already possess from various sources as to the extreme south-east districts will be dealt with after Dr. Ball's examination of the region now being under taken.

is from Alagi via the Qoleib well. Not having personally crossed this road, I am indebted to the Inspector General of Mines for the following note. "Um Hebal is on the main caravan road going south to the Murrat Wells in the Sudan. After leaving Um Hebal there are sundry reservoirs in the hills, but these are available only after rain ; later the road forks, the direct south road passing Bir Negib (salt) and then on to Bir Haimur, then the road again forks, one branch going to the south-east into the Bisharin country, the other south inclined to west to Ongat well and thence to Murrat. From the fork first-mentioned the road turns S. W. to the Bir Qoleib, containing a never failing supply of salt water, but not appreciated for its medicinal qualities, this well is situated about 2 miles off the Wadi Alagi down which the main caravan routes run until it divides at the north of the great Wadi known as the Gab-Gabba, the latter being the direct route to the Sudan. There are several days march to water, the more general route would be to follow the Alagi to Ongat well."

Dealing with the eastern side first—that is with the roads followed by Messrs. Villiers Stuart and Charteris Stewart and the writer, we have Charteris Stewart's report that there is an abundant supply of water in galts in the Shigagat and Oyamtib hills. Further south, and considerably to the east, Villiers Stuart obtained sufficient water for his purposes in a galt at Gebel Seiga (see map). The galt was discovered in a somewhat peculiar manner. While mapping he noticed some men on the summit of the neighbouring ridge, and called the attention of one of the camel-men to the fact, remarking that there must be water in the neighbourhood. Thereupon the Arab addressed volunteered to search for it, and following in the tracks of the men, found sufficient water for the needs of the party. It may be remarked in passing that the writer has invariably found the presence of hornets to be a sure indication that water is not far distant. The best known well in this district is, however, that of Haimur, where there are seven openings in the valley gravels at a depth of about 2 to 6 metres, but in only four of these was there water, so it is obvious that not too much reliance must be placed on this source of supply. Its importance can be gauged by the fact that during the period of the Mahdist rebellion a considerable number of Ababda were stationed here, a fort also serving to defend the road at this point. In this portion of the country there are several other wells. To the north-west is El Negib, on the Um Garaiart-Aswan road, consisting of a couple of wells from 5 to 6 metres deep, the water being, like that of Haimur, of very indifferent quality. To the east lie the two Murra wells, one brackish and the other bitter.

COLUMNAR LAVA, SUMMIT
OF GEBEL SUFRA.

HOLLOWED GRANITE BLOCKS
DENABT EL QOLAIB.

ANCIENT MINE AT GEBEL SAIGUR.

The latter is quite undrinkable, but the former is stated by Villiers Stuart, who was obliged to use it, to be astringent rather than salty in character. *

But far superior to all these---indeed Charteris Stewart reports it as the best water met with by him—is the Ongat pool. It is situated in a ravine among the granite hills of Ongat; the water is of excellent character, and was used by the party during the measuring of the Muqsim base line. About 50 kilometres due east is the well of Jugub, which also contains good water though uncertain in quantity, but was not actually visited.

At the present time the Um Garaiart mine is condensing its own water, but formerly the miners here and at Seiga mine obtained their supplies from the Ongat source.

Reference may be made to Um Niet (Um Itri of Colston) far to the east in the Daraheib direction, which was not however visited. It is stated by the Arabs that there are ruins at Um Niet, and that the well is built of stone. Colston describes the water in this neighbourhood as excellent.

On the main road from Um Garaiart to Alagi, there is the Um Qolaib well up a side valley, but in view of the abundant water supply, it is not generally required. Owing to recent rains the water was good at the beginning of 1906, but this is not generally the case.

Reference may also be made to the important notes as to water supply, mines, etc., in Linant de Bellefonds' *L'Etbaye*, especially on the road from Aswan to Hegatt, Daraheib and Gebel Elba.

Summarizing the water supply on the principal roads, we have :—

1. *Road to Emerald Mines of Sikait.* — Edfu. — Bir Abad. — Kanais (new well). — Baramia. — Dungash. — Sammut or Sibrit. — Murra.— Migif. This road divides into two branches; (*A*) on the road round to the north we have :—Wadi Ghuel pools—Galt Um Tundeba—Zubara pools (after rains).—The two Wadi Ghadir wells.—Small supply at Sikait (plentiful after rain). (*B*) The other road:—Pool at head of Wadi Nugrus (Megal el Harami). — Pools in Wadi el Nom. — Sikait Emerald Mine.

2. *Kom-Ombo — Sikait Road for Emerald Mines.* — Kom-Ombo. — Galt Um Sellim (often dry) and 10 kilometres to south the well

* Attention may also be called to the Um Rilan wells, south eastward of Um Garaiart, which have not, however, been visited by any member of the Survey.

in Wadi Ligaia.— Heliwat (dry when visited).— Um Gubur.— Bitter Wells of Abu Had and finally Sikait.

3. *Sikait to Bir Shadli.* — Good supply after rain in Wadi Huluz (Galt Um Gerifat, see map). — Bir Shadli or Abu Hamamid best water centres for visiting the Abu Hamamid district, unless there is water in Huluz.

4. *Edfu to the Red Sea via Wadi Lahami.* — Edfu. — Kanais. — Sammut or Sibrit. — Um Gubur. — Bir Masur.— Bir Metawit or Bir Ghashab as alternative.— Bir Shadli.— El Selaia.— Galt Um Gunud.

5. *Sikait to Abrak.* — Sikait. — Abu Khalga.— El Ranga (poor).— El Gulan. — Amar Spring. — Galt in Wadi Lahami. — Abu Beid.— Abrak.

6. *Aswan to Abrak and back.*—Aswan—Abu Hashim (see Floyer). — Abrak (two wells).— Abu Saafa.— Um Rait.— Um Hebal.— Aswan.

7. *Abrak to Alagi.* — Abrak. — Abu Saafa. — Um Rait — Shigig Hills, or Oyamtib. — Haimur. — Um Garaiart. — Um Qolaib. — Alagi (on the Nile).

8. *Alagi to Murat Wells.* — Alagi. — Qoleib. — Um Garaiart. — Um Irrelane. — Ongat. — Road then leads to the wells of El Murat.

9. *Aswan to Um Garaiart.*— Aswan.— Um Hebal.— Um Negib.— Um Garaiart but usually Allagi and direct across desert to Um Garaiart.

10. *Kom-Ombo to Abu Hamamid.*— Kom-Ombo.—Northern Qoleib in Wadi Kharit, 85 kilometres south-east of Kom-Ombo.—Galt at Ghorab Rean (dry). — Abu Hamamid. — Bir Shadli.

11. From Linant de Bellefonds : — Aswan. — Um Hebal. — Wadi Guéhettré. — Giengoub (well dug). — Hegatt.— Daraheib (springs).— Wadi Afferiame.—Wadi Massarié (for Chawanib workings).—Chenna valley. — Wadi Meica. — Mount Elba at Wadi Oyometerre. — Wadi Hesser (on sea), water salt but abundant. — Return to Meica (very little in well). — Wadi Beda. — Abu Saafa (name not given).

On the following page will be found tabulated results of analyses (by Mr. Lucas) of the water of some of the wells above referred to.

VEGETATION OF EASTERN DESERT.

The Eastern Desert is not a single unit as regards the character of its scenery, the country to the east of the central ranges being very different from that to the west. In the great eastern valleys, Ghadir, Gemal, Hafafit, Lahami, Huluz, Abu Beid, etc., are many spots rendered beautiful by the abundance of seyal trees and markh bushes *(Leptadenia)*, graceful tamarisk and spreading arrak *(Salvadora)*, while here and there a *Balanites (Arab.* hegilig) attains giant size. When one considers the surroundings in which the trees are found, one is struck by their hardihood.

The wide watercourse to the east of Hamata is filled with the dried grass known to the Arabs as "shush" (*Panicum turgidum*), while the palm oasis of Abu Saafa, the seyal grove of Abu Beid, and the wide valley of Hodein filled with the sickly green *Calotropis procera*, with its fleshy leaves and large pod, remain as pleasant memories.

On the western slopes in the upper reaches of the mountain valleys many a pleasing picture is presented, where spreading seyal trees are dotted along the watercourses, as in Abu Hamamid, Ghashab, etc., while the larger wadis descending to the Nile always contain a varied if somewhat dry vegetation.

Apart from these isolated instances, the western side of this desert is in very truth a region of desolation, and more especially so to the south-east of Aswan, where blown sand is piled in ridge and dune against the gaunt slopes of the bare hills, and mirage distorts their outlines into fantastic forms. Wind-swept, waterless and barren as the district is, the traveller's only aim is to cross it at maximum speed, unless some geological feature arises to attract his attention and arouse his interest.

EA

Ingredients Milligrams per litre (parts per million)	Sammut	Helie	Geleb	Abu Hamamid
Total Solid Matter in Solution	1399.0	4040.0	1000.0	1720.0
Chlorine.....	322.7	323.0	59.0	225.0
Equivalent of Chlorine as Sodium Chloride.....	530.0	530.0	97.0	370.0
Sulphuric Anhydride	272.9	1446.7	373.1	318.2
Equivalent of Sulphuric Anhydride as Sodium Sulphate.....	484.7	2569.0	662.0	565.0
Alkalinity to Phenolphthalein calculated as Sodium Carbonate....	nil	nil	nil	nil
Alkalinity to Methyl Orange (less that due to Sodium Carbonate) calculated as Sodium Bicarbonate	..	651.0	327.0	848.0
Lime.....	170.0	610.0	110.0	330.0
Magnesia	76.8	211.6	37.7	86.9

The samples were too small to admit of any further determinations. In some cases a certain amount of dec
is probably due to a bacterial reduction of the sulphates.

\T WELLS

late)	El Masur	Metawit	Sikait	Haimur	Baramia	Dungash	Bir Adiela (Northern Sudan)
)	880.0	4020.0	7360.0	6260.0	1616.0	3144.0	1136.0
)	57.0	1027.0	1263.0	378.0	322.7	770.3	83.3
)	94.0	1687.0	2075.0	627.0	530.5	1265.4	136.8
)	262.7	1042.0	2529.6	229.4	96.0	731.1	301.7
)	466.0	1850.0	4492.0	4074.0	170.5	1298.2	535.8
	nil	nil	nil	nil	74.2	47.7	42.4
)	222.0	550.0	500.0	378.0	403.2	457.8	193.2
	200.0	350.0	..	..	110.0	384.0	230.0
	29.0	115.9	..	..	137.7	239.2	61.6

place during transit with the formation of free sulphur, sulphuretted hydrogen and sulphide of iron. This

GENERAL NOTES.

It might have been expected that this desert region would have remained untrodden by foot of man, but on the contrary, there is evidence in every part of the region of life and movement, especially in connection with the quest for gold. The great valley which connects Edfu and the Baramia mine bears special witness to this fact, a small temple having been hewn out in the sandstone scarp, while three central rows of pillars support the massive roof of superincumbent rock. Coloured hieroglyphic records crowd its walls, and the inscriptions record the discovery of mines and the construction of wells by the great Seti. The old cisterns so constructed may be those still preserved at Abu Rahal, and near the eastern edge of the sandstone scarp in Wadi Baramia.

At Baramia the whole hill-side was quarried by the old workers, many of the stone ore-crushers and basins still being found in the neighbourhood of the ancient buildings, while wooden scrapers have also been obtained.

Further to the north, important workings have been located at many spots, and the marble ridge at Atafla has evidently been extensively quarried, but as these will form the subject of more detailed examination, they need not be further referred to here.

Ruins and ancient workings exist to the north of Gebel Abu Khrug, at Um el Huetat and Gebel Atut, as well as in the Wadi Hangalia, on the north-east flank of Gebel Nugrus.

Further to the east are the extensive ruins of Dweig, but the object for which they were built has not yet been ascertained, and at the emerald mines of Sikait and Nugrus we find ample evidence of important occupation. Nothing is more striking than the number of ruined buildings in the Wadis Sikait and Nugrus, some of the buildings being of a size unusual for the desert. Macalister mentions at least five such ruined settlements, and in his description, *he points out a great variation in the quality and finish of the houses.

The rock temples of Sikait have naturally also aroused much interest, and a good photograph of the best of these which is cut out of the solid rock overhanging the soft talcose schist is given in Flover's Etbai (at p. 47.) The temples themselves are small and the chambers are plain, the largest being some six metres square. Macalister re-

* Geog. jour. 1900. p. 546.

marks :—" Steps lead up to this chamber from the wadi. During the excavation of the interior, columns of rock were left and afterwards rudely shaped. Mr. John Belcher, A.R.A., to whom I have shown my rough sketches, is of opinion that the pillars are Egyptian, showing signs of Greek influence, but that the work is very primitive. At the inner end of the chamber is a recess raised about two feet from the lower floor, approached by steps and divided into three compartments. Each division contains an altar. On each side of the temple are low chambers about four feet high. The walls of the temple bear faint traces of painting."

Floyer also mentions a second temple with a Greco-Roman inscription, regarding which one has sadly to record that one-third of the whole has been removed in quite recent years.

But though Sikait and the emerald district show most marked evidence of the active mining operations of the past, there are many other localities among these hills where stone buildings still remain to indicate the near presence of ancient workings. Among these, those of Zubara, Sukkari and Um Kabu, by their abundance, indicate the importance of the mining centres which called them into being.

The evidence of ancient activity is again met with in the lower country to the east of Hamata, but in general there is no obvious connection of this area with any known mining locality. Thus, where Wadi Gau enters Abu Ghusun there is part of a well-made wall with stone circles on both sides in the centre of the latter valley, but there are no ore-crushers.

The stone buildings clustered at the head of Wadi el Gulan are exceptional, for on the slopes are several ancient workings and rubbing-stones. Again in the broad valleys of the Rod el Hashabab are many stone-circles, and the amount of quartz lying near one of them points to their having had some connection with the mining industry. Further south is a very large well-space now filled up, the rectangle enclosed by it measuring roughly 21 by 8 metres. A small seyal now occupies the slight central depression.

After leaving Amar spring, there is a very well-built ancient well at the point where our road enters Wadi Lahami, but, like those above-mentioned, it was empty. Further to the west there are three stone-circles on the north side of the valley. History is silent as to their exact age, and to find dated memorials we have to turn to the group of springs at Abrak. Here a fort dominates one of the principal wells and Colston has described it (loc. cit. p. 526) as of Greek construction, and containing many fragments of Greek inscriptions

too mutilated to be deciphered. He regards it as being the hunting station of Ptolemy Euergetes.

Linant de Bellefonds, on the other hand, suggests that Abu Saafa well (not specifically named, but described on page 164 of his *L'Etbaye*) is possibly the hunting station. He mentions also the temple facade in high relief carved on the sandstone, while on a small hieroglyphic tablet he was able to distinguish the name of the Ptolemy above-mentioned.

One of the plates in Linant de Bellefonds' work is devoted to illustrating this striking locality. The facade and the *Calotropis* plant in front of it are somewhat exaggerated, but the hills themselves are well reproduced.

South of this point the writer has not seen any ruins of note, but the localities where ancient mine buildings occur are mentioned subsequently in connection with the mines themselves. Between Um Garaiart and Alagi there are numerous well-preserved hieroglyphic inscriptions on the sandstone scarp where the road crosses from the schists into the sandstone area.

PART II.

GEOLOGY.

The portion of the south-eastern desert studied embraced a district extending between latitude 25° and 22° N., the portion more especially considered being the central area of the desert between longitude 30° and 35° E. As in the topography of this region we recognize three salient types of scenery, so the rocks represented fall into three great groups, on the west bordering the valley of the Nile, but often extending far into the desert eastwards, these being :(1) The sterile regions of the Nubian sandstone. (2) East of these are the extensive series of plutonic rocks (granites, diorites, gabbros, etc.) which form great mountain ranges or wind-swept plain. Thirdly, there is a vast area occupied by metamorphic and sedimentary rocks of ancient date varying from gneissic schists of highly foliated type on the one hand to clay-slates and conglomerates on the other.

EOCENE.

Eocene Strata south of Kom-Ombo Plain.—The present season's work has, however, resulted in an interesting advance in our knowledge as to the distribution of the Eocene and Cretaceous rocks, the former having now been found south of any previously recorded locality. It is already well known that owing to fault effects the Lower Libyan beds with characteristic Eocene sea-urchins are present in low ridges at the northern edge of the Kom-Ombo plain, notably in the neighbourhood of Ragama, and much further to the east behind a well-marked white hill of Cretaceous limestone. Ferrar has now shown that a typical Nummulitic limestone with Lower Libyan oysters also occurs in Wadi Allowi on the south side of the Kom-Ombo plain.

CRETACEOUS.

Distribution of Cretaceous Beds.—This year's study has also shown that the Campanian beds of the Cretaceous, with all their characteristic features, viz. *Ostrea Villei* phosphatic beds and silicified cherty strata, are by their superior hardness the main contributing cause of the plateau summits in the high hills behind Edfu, Serrag, etc. In general the oyster limestone breaks up into great rectangular slabs which slip down the hill-side as the soft beds are eroded from underneath them. Using these as an index, Ferrar has shown that the Cretaceous beds have a wide extension inland. They have been noted by him as far as Abu Rahal, over 40 kilometres east of the Nile, and

Gebel Nugra, where he reports that the mass of sandstone seems to have stood firm while the upper limestone and coprolite beds have been faulted down on both sides of it, and may now be seen dipping away from the hill at angles of from 5° to 10°. Other localities recorded are on both sides of Wadi Kharit near Bir Qoleib, Gara el Huwi on the Redesia-Berenice road, on the watershed between Wadi Serrag and Wadi Abu Midrik, and at the confluence of Wadi Um Sellim. In the Kom-Ombo plain attention has been previously called (Meyer-Eymar, Schweinfurth, Beadnell) to the white Danian limestone, in which Ferrar and the present writer have also obtained *Ventriculites poculum* and *Ostrea vesicularis*.

Width of Nubian Sandstone.—The Nubian Sandstone is very widely extended, having an average width of 100 kilometres, varying from 168 kilometres between the river and Abrak to 45 kilometres in the neighbourhood of Alagi.

The alternation of sandstones and salty clays is the main feature of the Nubian sandstone near the Nile valley, and a deep boring made by Figari Bey in Wadi Huwi south of Redesia, near Edfu, is of value as exhibiting the true succession. These, from above, were as follows:—

1. Alternating strata of yellow marly sandstone, greenish marly clay and grey ferruginous quartzose sandstone with thin beds of fibrous gypsum, rock salt and veins of red ochre	30	m.
2. Horizontally bedded strata of micaceous white or light grey laminated sandstone with plant traces	13	„
3. Shaly, ash-grey clay with pyrites nodules and thin veins of a bituminous substance	3	„
4. Alternating beds of ash-grey clays and sandstone...	10	„
5. Black bituminous paper shale with carbonized plant remains of a reed-like nature	0.5	„
6. Chloritic quartz-grit, alternating with chloritic clays and at varying depths two beds of black paper-shales with lignite	10	„
7. Ash-grey micaceous clays...	17	„
8. Grey-green compact siliceous limestone with small Oysters. Figari names *Plicatula cfr. spinosa*, *Lima*... ...	0.5	„
9. Black bituminous micaceous clay	0.3	„
10. Grey-green limestone like No. 8	0.3	„
11. Calcareous very compact sandstone without fossils .	0.5	„
12. Regular alternations of laminated, micaceous clayey grit and ash-grey clay	40	„
	125.1	m.

At a depth of 100.6m. a strongly water-bearing stratum was met with, which hindered the continuation of the work, but renewed boring has shown that the same gritty and clayey beds without lignite extend to a depth of 122m. The borer then traversed 30.5m. of compact ash-grey " clay " (called " tufo argilloso " by Figari) with beds of soft grit and a hard dolomitic bed. At 262m. the boring had to be abandoned owing to an accident, the crystalline rocks not having been reached at that depth.

The greatest interest attaches to the leaf-beds, and the writer has now found these coming to the surface in a small valley near Gebel Serrag, where they are overlaid and underlaid by sandstones, while in a well now being dug by the Mines Department at Abu Rahal,(*) a very interesting deposit has been obtained at a little over 50 metres, containing carbonized plant remains, and very numerous examples of *Lingula* and a mytiloid shell, the fauna being new to Egypt. Taking this in connection with the carbonized leaf-beds from Sakiet el Ter and Abu Radham in Wadi Qena, specimens of which were brought to the writer by Mr. Trevor of the Cairo Syndicate, it is evident that these beds are of more than local occurrence. *

To the south of Darau the hills are a monotonous waste of sandstone intermixed with green clays, but where seen in railway cuttings, the latter occur as pockets rather than as regular layers. The colouring matter (ferruginous) of the sandstones also increases in the direction of Aswan, being probably connected with the proximity of the granite from which their materials were derived.

In passing from the Nile eastward, there is a general agreement that the marl or clay-sandstone facies changes to one in which the beds are more massive, ferruginous and current-banded, though the beds either remain horizontal, or have dips not in general exceeding 5°, but which often alter from east to west and vice versa.

In Wadi Baramia the change takes place at a well-marked black hill east of Abu Rahal Well, the ferruginous quartzites here almost becoming ironstones, while the soft sandstones show remarkable evidence of false-bedding and good jointing, in many places being also spotted with ferruginous aggregations. Further east the clays completely disappear, and the succession exposed now becomes a white or spotted

* The writer and Dr. Ball have during the summer had the opportunity of studying the specimens brought by Mr.Wells from this locality at the Natural History Museum, London, receiving kind help from Dr. Andrews and Mr. Bullen Newton. Among the forms recognized is *Septifer linearis* cf., differing but little from English Gault specimens; a scale of the Ganoid fish *Lepidotus* common to Jurassic and Cretaceous strata, and from Abu Radham a tooth of *Ichthyosaurus campylodon*, the aspect of the fauna being thus markedly Cretaceous.

sandstone, alternating with ferruginous or manganiferous bands showing concretionary structure. Incidentally it may be mentioned that the slopes here are much more covered with sand than those to the west, the material being apparently brought from the granite region lying to the north-east.

In Wadi Shait, Stewart mentions a fine laminated sandstone interbedded with highly indurated marls and beds of chert, in many places much current bedding being noticeable, while at Galt Um Sellim the sandstones seem to be more massive and in certain places, which look as though water had trickled over them, there is a deposit which is probably calcareous. The flatness of the beds is noticeable throughout, although there are occasionally slightly opposing dips. There are numerous ferruginous black bands and concretions, the most noticeable being those high up a hill on whose sides Stewart notes some remarkable igneous gravels and loose drift.

Base of Sandstone.—Ferrar remarks on the general distribution of a conglomerate of quartz and other pebbles at the base of the Nubian Sandstone. "The size of these pebbles, which are water-worn, varies greatly. Sometimes they average 2 cm. across and are merely sprinkled in a matrix of coarse sand-grains, while at other times they are as much as 10 cm. across, and are only held together by interstitial sand-grains. The thickness varies, being 20 metres in the escarpment at Rod el Naaghi, in Wadi Natash it is represented by two beds each ½ metre thick, and in Wadi Kharit by a coarse sandstone 5 metres thick in which are scattered occasional quartz pebbles."

For the first 30 or 40 kilometres Wadi Shait, Wadi Natash and Wadi Kharit lie in a broad plain enclosed to a large extent by high sandstone cliffs of varying height, the maximum noted being at Gebel Nugra, 218 metres above Wadi Natash. Near the longitude of Sammut well the valleys widen out, and the sandstone forms an escarpment trending north and south, which at Dungash shows a red earth underlying the sandstone (see plate I.). Further south, the study of this rock wall shows a new and interesting feature, viz., the presence of volcanic rocks underlying the Nubian sandstone. These are of very wide extension. Near Dungash they are first met with in the form of a basalt immediately overlying the red earth, but the composition is variable, some of the members being rhyolitic and andesitic in composition, while in the Rod el Naaghi Dr. Ball finds a thick sheet of diabase, with well-marked ophitic structure, under the sandstone. The extent of the volcanic activity is further marked by the

GRANITE COUNTRY, NORTH OF BARAMIA MINE.

EXFOLIATING GNEISSOSE GRANITE, NORTH OF GEBEL EL HEDA.

structure of several important summits in this neighbourhood, the most noticeable being Gebel Sufra, whose columnar structure is one of the most marked of its features (see Plate III.). The base of this hill consists of the older syenitic and dioritic rocks, the newer volcanic members being limited to the highest portion at its northern end, though there appears to have been an extensive lava flow on its south-western border. The evidence does not justify us in regarding Sufra as a volcanic neck, but future observers may find points favouring this view.

Gebel Nazla, another high hill to the south, presents very similar characters, and the two well-marked isolated hills, El Nahud, have been found by Ferrar to be volcanic necks. The basalts, etc., increase in importance as Wadi Natash is approached, and in consequence of their presence the sandstone boundary turns sharply eastward, but at present has not been traced far. All the principal hills in this neighbourhood are composed of volcanic rocks, while the sandstone is displayed in broad plains between them. The southern boundary of this eastern extension of the sandstone passes Gebel Derrera and extends towards Muktil. The next point at which the sandstone was met was at Goleib Hills, nearly 40 kilometres south of Bir Shadli, which hills appear to be only a huge westerly outlier of the main escarpment. The beds here consist of typical sandstones lying horizontally and without volcanic rocks. Still further south, the main sandstone escarpment is again met with, trending ESE. towards the Abrak Well, the sandstone still retaining its typical characters, but having a low dip, roughly NNE. At this point the hills themselves were crossed by Stewart, and a plain to the south of Um Harba displayed fossiliferous strata of considerable interest.

Fossiliferous Beds of Um Harba.—Stewart reports that these occur in low ridges in the plain itself, and have a well-marked curvature. To the SW. they are bounded by sandstone beds with a dip of 15° (estimated), while to the NE. is a cliff of granite capped by sandstone, which further east is formed of sandstone only, the granite having entirely disappeared. Owing to circumstances, the beds could only receive cursory study, but all the indications point to faulting on a considerable scale.

The fossils themselves differ from those previously recorded, and include bones recognised by Dr. Andrews as crocodile scales, very numerous gasteropoda of scalaroid and naticoid type, and bivalves.

On crossing the watershed and following down Wadi Silsila for a few kilometres, nothing but sandstone is met with (with the exception of a few clay bands) until the wadi emerges upon the broken igneous plain of Abrak. Just where the Wadi Silsila debouches into this plain, there is a well-marked fault showing the lower beds near it to be rather turned up, while those a little further from the fault to the west do not dip so much to the westward.

The Abrak well is situated exactly at the foot of the sandstone just where there is a sharp synclinal flexure in it. Hitherto dislocation has been inferred, but at the second Abrak well it is very clearly marked.

The upper sandstone beds are horizontal, but as we descend they become slightly bent, and terminate at their junction with the igneous rock in a crush conglomerate cemented by silica, the whole suggesting faulting by overthrust. Further south, at the second Abrak Well, faulting is in the opposite direction, the gneissose rock being plastered against the highly tilted sandstone. This character is displayed in the steep escarpment which extends south-east of Abrak.

The Abu Saafa spring is due to a gentle folding of the sandstone, there being a dip of about 4° in opposite directions. The water descends the joints and forms a perennial spring.

The sandstone around Abu Saafa appears to be a broad tongue projecting eastward, as on passing southwards one enters the granitic region south of Owamtib, this prominent peak being still formed of Nubian sandstone. This is the last point at which Nubian sandstone was observed, and from here it apparently trends away to the west.

Evidence of Former Extension of Sandstone. — Stewart reports that he finds evidence of the former extension of the sandstone in Gebels Seiga (905 m.), Abu Um Tenedba (900 m.), Raitit (825 m.), Abu Rahia (835 m.) and the two Gebels Zerga (360 m.), on whose summits are small caps of sandstone.

The sandstone was also met with north-west of Um Garaiart Mine, the physical characters being typical. It extends southwards for many kilometres, and forms a bold escarpment overlooking the broad valley of Gab-Gabba.* One point of special interest was the discovery of a fern in the sandstone near Um Garaiart. †

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* At the foot of the escarpment is a wide gravel or pebble beach. Outliers of this same gravel occur in the plains of the Wadi Haimur and also near the mouth of the same wadi, and have been worked for alluvial gold at these places. — J.W.

† This fern was submitted to Mr. Seward, F.R.S., by whom it has been further studied. In external characters it has strong resemblances to the Carboniferous *Pecopteris* and the Wealden *Weichselia.*

Gebel Seiga is certainly the most remarkable example of outlying sandstone as it is 120 kilometres from the eastern edge of the main sandstone plateau and 65 kilometres from Owamtib to the north; there is, however, the possibility that a strip of sandstone occurs away to the east, near the coast.

Gebel Um Tenedba is also an interesting hill, as here we have granite weathering into boulders like those at Aswan at its western foot with bands upon bands of varying qualities of gneiss forming the mass of the hill. There are also one or more bands of interbedded (?) moderately coarse mica-schist, the whole having a fairly steep easterly dip of some 10° to 15°. On the summit there is a practically flat-bedded cap of sandstone.

Gebel Raitit is a hill composed of fine and coarse gneisses, with what look like bands of schists (they may be crushed dykes). The strike of these gneisses in most of the surrounding country is 245°-250° (NE-SW) and the dip is almost vertical but inclining to the north. The top of the hill is capped with some 20 metres of horizontal sandstone.

A further point of interest, showing the former extension of the Nubian sandstone, has been noticed near the shore of the Red Sea at El Ranga, where the Nubian sandstone, with a well-marked interbedded andesite, dips somewhat steeply seaward.

Summarizing, the Nubian sandstone presents itself under the following aspects:—

1. It rests on the older rocks, the latter presenting a flat denudation surface corresponding to the dip of the sandstone; this is the Wadi Baramia type.
2. It is associated with bedded or underlying volcanic rocks: the El Ranga and Natash types.
3. It has been faulted against the older igneous and metamorphic rocks—the Abrak type.
4. It caps hills thus forming outliers in the central desert region; the Seiga type.
5. It is present on the Red Sea border together with volcanic rocks.

METAMORPHIC ROCKS.

The main portion of the country studied, as already stated, is chiefly igneous, composed of a group of rocks (foliated and unfoliated), and a metamorphic schistose series. The latter series, which will now be considered, is very variable in its nature, and demands a careful microscopic study before its true relations can be finally established. On the field evidence, it may be considered under the following divisions: Serpentine, Baramia Rock and Schists. It is evident that these are of very wide extension, as they have been observed from Baramia and Dungash in the north to Wadi Murra and Muqsim on the south—that is over nearly 3 degrees of latitude.

Serpentines.—The Serpentines are as a rule dark green to black in colour, but usually display yellowish alterations on the fractured surfaces. Their specific gravity, so far as examined, varies from 2.5 to 2.7. They are frequently highly magnetic, and cause great deviation of the compass-needle in their neighbourhood.

The principal centres for this rock are the Baramia-Dungash area, in well-marked cliffs at Bir Murra in Wadi Shait, in Udeh el Anz, near Jebel Derrera, in the Um Khariga and Ambaut hills, north of Sikait, also near Sikait and on Gebel Sikait, and near the Murrat well in the southern Muqsim area.(*) These rocks, which are intimately associated with the schists, are usually too much altered to indicate with certainty their source of origin, such structure as still remains suggesting their derivation from peridotites, which appear to be intrusive in the schists.

Baramia Rock.—Apparently closely related to these is a special type to which the name of Baramia rock has been assigned, owing to its conspicuous development at that locality. It is of a light creamy colour, very soft and talcose, weathering into cavities sometimes 30 centimetres across giving the rock a cavernous appearance. In the valleys north of Baramia it occurs in a vertical position interbedded with the green schists, while further south it lies more horizontally upon a hackly schist. At Dungash it dips at a steep angle, and is again closely associated with the schists and serpentines, it being apparently in close relationship to the latter rock.

To the south-east towards Wadi Hamish, it forms a definite layer overlying very finely laminated paper-schists and determines a range

* Also north of Um Garaiart in the neighbourhood of the Qoleib well and Um Eshera.—J. W.

trending nearly due east and west, while the beds are tilted at a high angle, in the main northward. It again reappears from time to time in the confused hill country to the north of Wadi Shait, between Gebel Abu Khrug and Sufra, being in all cases associated with the green schist.

The Baramia rock again reappears in the region north of Sikait, where it is associated with graphitic and more nondescript varieties of schists traversed by dykes. Its characters in this neighbourhood suggest its being a contact alteration or crush product from the schists when in contact with a dolerite dyke, while at Kurdeman it had more the characters of a serpentine.

It again occurs at Sukkari between crushed schists and dolerite veins, and in my field-notes for this region it has been described as the Baramia crushed serpentine. It is again found on entering Wadi Um Ghadir.

The cavernous rock is a conspicuous member of the emerald-bearing schist series, and the temple at Sikait is cut in this material.

The probability that serpentine and Baramia rock are of similar nature is strengthened by the fact that when the former reappears in Wadi Murra, the latter reappears with it, an almost conclusive fact when it is remembered that the nearest exposure studied to the north was 250 kilometres distant. At any rate, this shows the intimate connection of both with the schists.

From this point onwards the rock is a conspicuous feature between Murra and Um Garaiart. Here many of its previous characteristics were renoted, such as alternation with paper-schists.

We may state in conclusion that the Serpentine and Baramia Rock are closely associated members of the schistose series.*

Talc Schists.—Dr. Ball reports very pure talc schists to occur plentifully in the group of hills called Um el Huetat, about 10 km. W. of Gebel Atut, where there are some old workings in this material. Talc schists are also met with at Sikait and Zubara.

Chloritic and Hornblendic Schists.—These rocks are of very wide extension, and, in general, closely associated with those previously mentioned. They are one of the main features in the Baramia district. Green to light-blue schists were noticed on ascending the wadi towards Hagar Dungash from the east side, also between the south end of

* Two sections were made from specimens regarded as typical Baramia rock. One from near Sikait is largely composed of Talc and a mineral requiring further study; the other present N.W. of Um Garaiart is a serpentine.

Gebel Sufra and Wadi Shait and again close to the Sudan frontier in the Nile Valley Company's cairn hill to the west of Gebel Muqsim (see plate II). In the latter place they were very much puckered and crumpled ; and at one spot near here looked almost sufficiently sheared for a commercial slate. In the northern portion, to the east of Gebel Muelih hornblende schists pass almost imperceptibly into diorite gneisses, and frequently contain large quartz-veins, the largest of which forms the hill called Erf el Fahid.

ANCIENT SEDIMENTARY ROCKS.

Schists of Volcanic Materials and Ancient Lavas.—In the Eastern Desert and in the Sinai Reports attention has already been called to the evidence of volcanic action previous to the intrusion of the granites, in the shape of lavas of various types, agglomerates and tuffs.* These intrusions are again of wide distribution in this southern portion of the desert.

Leaving aside the main rock of the Dungash district for further study, the most notable and characteristic conglomerates have been met with both in a small valley N. and SW. of the mine. Further south, after crossing a wide granitic plain, the road from Dungash to the Wadi Hamish passes between a range composed of Baramia rocks and paper-schists on the one hand, and on the other low hills composed of a well-marked amygdaloidal melaphyre and a doleritic rock, together with finer varieties. This rock, though in the schistose area, has a strong resemblance to those noted in the Nubian sandstone, and may consequently belong to the younger series.

The schists south of Wadi Shait share the eastward bend of the sandstone and its associated volcanic rocks. Ferrar reports on the schistose belt to the east as follows :— " Five kilometres west of Gebel Nahud, and at the confluence of Wadi Khrug with Wadi Natash, is a range of hills consisting of schists. These occupy a narrow strip of land which is crossed at right angles by Wadi Natash, and which causes Wadi Khrug to assume a straight course parallel to the outcrop of

* A much wider study than the writer has yet been able to give this point will be required before we can differentiate between the true sedimentary rocks, the sedimentary rocks made up of volcanic material, the true lavas, and the deeper-seated more highly crystalline rocks connected with them, which play so great a part in this desert. Only careful mapping of typical areas can solve the problem satisfactorily. M. J. Couyat of the French Geological Survey has in this connection called my attention to a study he has made in Normandy (not yet published) where the microgranite of Bouillon (Orne) at its contact with the sedimentary rocks (Silurian) has formed an igneous breccia. Here the outer zone of the magma has cooled and therefore solidified more rapidly, being in consequence of finer grain. A subsequent movement has broken up this outer zone whose fragments have been recemented by the magma still remaining in a fused condition. This method of formation may be of very wide extension in Egypt.

the rocks. They strike almost due N. and S. and dip to the east at angles varying from 20° to 40°. Numerous quartz reefs occur here. The length of this belt has not yet been determined, but its breadth is inconsiderable, being barred on the east, at the foot of Gebel Nahud, by the gneissose granite of the Nahud plain.

" Similar schists were encountered at the head of Wadi Antar. At the foot of Gebel el Heda, on both sides of Wadi Antar, a belt of schists appears from the hills east of Gebel Nukheira, passes close along the foot of El Heda, and seems to form the hilly country on the south side of Wadi Antar between Gebel el Heda and Wadi el Anz. These schists in the main, strike roughly E. and W. but the dip is more variable, though as a general rule it is between 40° and 60° to the SE.

" A great variety of rock is displayed in the different bands which make up the belt, and at first glance they have exactly the appearance of variable marls, sands and clays which have been violently contorted. On closer examination the rocks proved to be iron-stained quartzites. The beds which make up the mass maintain uniform thicknesses for great distances. As the hills to the south and west of El Heda are arranged in rows parallel to the strike of these schists, and as schists occur along nearly the whole length of Udeh el Anz, it would seem that this area, which lies between Wadi Antar and Wadi Ghashab, consists mainly of schists."

The next appearance of rock of possibly ancient volcanic origin was in Wadi el Anz, where dolerites were interbedded with the laminated schists, which themselves still require further study. A similar combination was seen on the road from Hamret Mukbud to Bir Shadli. On both sides of the Abu Hamamid drainage line, dark hills composed of bedded dolerites and schists are conspicuous, the dip of these in one case being noted as 70° SW.

Bir Shadli is a typical locality for this group, dolerites, andesites and allied rocks being most conspicuous in the surrounding hills, while higher up Wadi Sheikh is an ancient conglomerate containing elliptical pebbles of dolerite with the larger axis up to 0.5m. in length. This volcanic region is of very wide extent, forming the great mass of Abu Hamamid and almost all the bounding hills of the Heluz drainage down to the entry of Wadi Gaetri where a gneissose district is entered. In addition to the dolerites, tuffs and purplish porphyries play an important part. Gebel Abu Gurdi (1562m.), further south, was found by Dr. Ball to consist almost entirely of schists of a similar character to those of Abu Hamamid, this group of rocks thus showing a large extension to the south.

The dolerites are again conspicuous in the hills north of Sikait, Lewewi, etc., and especially to the east and north of Zubara, where they have blackened the white schists enclosed between them, suggesting that the former were intruded into and not interbedded with these. In fact, the intermixture of dolerite and schists may be taken as the type feature of this portion of the country, being present in the neighbourhood of Sukkari and extending round the granite-mass of Gebel Nugrus as far north as Atut and Igli, and including the great ranges of Um Khariga, Hangalia and Zubara.

To the east of Hamata, near the Red Sea, the rocks are largely of acid character (granites and gneisses), but near El Ranga are hills of diabase and porphyry, closely associated with many dykes. Conglomerates were also noted in Wadi Daut, but further south these are replaced by the granites.

Returning to the central portion of the desert, the dolerite and schists play an important part along the road for 30 kilometres to the south of Bir Shadli at least, although the road itself is in the main on the granite plain.

Additional information is now also available for the district to the west of this road, a region in which Gebel Ghorab is the most conspicuous feature. Ferrar reports:— " On the west side of Gebel Erefi a belt of banded rock, in general appearance very like the El Heda belt, crosses Wadi Kharit almost at right angles. This banded rock occurs between two similar masses of granite, with two masses of the old volcanic rocks on the outward sides of the granite. All the junctions are occupied by notable tributary wadis, which, on the whole, are parallel. The two exposures of granite occupy approximately equal lengths of the bank of Wadi Kharit. The main trend of the belt of schists is NNE. — SSW., but the structure lines strike and dip literally to the four corners of the earth. The rock appears to have been originally horizontally bedded; these beds seem to have been turned on their edges until they assumed a vertical position; then twisted round a vertical axis until the original position of the beds was entirely obliterated. The disturbed state of the rocks and an unusual abundance of pottery in the wadi bed suggest the presence of some product of economical value. At Gebel Ghorab an uplift has taken place since the deposition of the Nubian sandstone, and a single anticlinal fold along a N-S. axis has been produced. The top of the anticline has been denuded away to such an extent that the schists below the Nubian sandstone are laid bare. The cleavage planes of the schists dip to the west and the dip varies from 60° to 90°.

The strike of the cleavage planes is usually north and south. The rock is rendered very splintery by its numerous joints and cleavages, and weathers so easily that a basin has been excavated on the crest of the fold. Between this schist exposure and the base of the Nubian sandstone is a layer of rock, which seems to be a lava flow, older than the sandstone, but younger than the schists, but it is now so decomposed that a very close examination is needed to determine its field relations."

In Wadi Murra to the south the schists and conglomerates again make their appearance, the schists forming the valley floor, while the conglomerates determine a conspicuous range to the south; there is also a feature requiring further study in a black hill south of Wadi Abu Brush. *

Calcareous Schists and Marble Bands—Atafla Marble.—The next group of rocks presents considerable difficulties as regards its mode of origin, but its physical characteristics are well marked. This group only occurs in wide extension to the north and north-east of Um Garaiart, and especially in the neighbourhood of the Haimur drainage line. The rocks were first met with about 50 kilometres from Haimur where a biotite-gneiss country is succeeded by the marble region, a low marble hill with a marked curvature but generally trending SE-NW indicating its main eastern boundary. The great predominance of this rock in this district gives it the appearance of being covered with driven snow. The marble bands alternate with green schists, requiring further study.

The more calcareous members have a comparatively limited distribution westward, but seem to share the apparent general north-west trend which is the rule between Um Garaiart and Haimur, as they reappear to the north of Denabt el Qolaib (see map). The marble bands are sometimes in very close connection with the adjacent granite, and the question therefore arises whether some of these may not result from contact alteration of the calcareous schists by the igneous rocks.

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* In the map of the Um Garaiart concession in Mr. Wells' report previously mentioned, the wide distribution of the sedimentary schists and slates at that locality is indicated, also the position of the granites, as well as syenites and diorites, and the more indeterminate crystalline members. He recognized two sedimentary series, the earlier one resting on a granitic bed-rock while the later, consisting of slates, quartzites, and conglomerates, owes its origin to the disintegration of the older formation. There was a subsequent intrusion of plutonic rocks, especially diorites, crushing and crumpling the sedimentary formations, and giving rise to a considerable amount of regional and contact metamorphism.

The Conglomerates are of special interest as they contain huge fragments of the rocks of the land surface from whose denudation they obtained their material.

The question of the origin of these calcareous schists is one calling for careful comparative study.

Contact Alteration Schist (*Knotenschiefer*).—Some well marked beds with knotted structure were met with near the northern Gebel Qelaib at the foot of the sandstone scarp, and again on the south side of Wadi Seiga and Wadi Rodelbi.

Chlorite-Schists.— On the north side of Gebel Ribdab is a normal chlorite schist, while further south, on the eastern side of Muqsim, is a bright apple-green variety.

Near here also occur certain black schists of very doleritic appearance, which have, however, only a specific gravity of 2.6, and under the microscope are seen to be almost entirely composed of mica.

Graphitic-Schists. —Of considerable importance and interest is a type of schist which seems largely to be composed of graphite, this being of wide distribution, and especially so in the mining areas. Thus it is present as one of the striking constituents near the gold-lode of the Baramia mine, while in the Sikait neighbourhood it was noted in the emerald mine there, and as a constituent member of the schists in the lower part of Gebel Allawi north of Sikait. To the south these again reappear in the Um Garaiart gold mine.

The Mica Schists and Talc Schists of the Sikait District will be specially considered under the heading Emerald Belt.

Summary of Schists.

From a study of their distribution it is evident that the majority of the schists belong to one geological horizon, as when one member occurs in a district most of the others appear with it, although the areas themselves may be separated by wide distances. As already shown from a study of Sinai and the northern portion of this desert, volcanic action here also has played an important part in their formation. The calcareous schists stand somewhat alone, and are, in fact, more intimately related to similar rocks developed south of Wadi Halfa. The emerald-bearing schists are also of exceptional character.

ACID IGNEOUS AND METAMORPHIC ROCKS.

The chief members noted in the desert are (1) Granites (2) Gneisses. The majority of the foliated members bear evidence of having originated from unaltered granites, but there are others which cannot certainly be

traced to this origin, or are derived from granitic masses which have long lost their initial characters, being involved in regional metamorphic movements.

Gneisses East of Watershed.—For the typical Gneisses two areas are especially noticeable, the region which lies between Gebel Migif and Wadi Gemal and a district which lies just north of a line joining the Ribdab hill and Haimur Well.

Gebel Migif and Wadi Gemal.—In descending Wadi Huluz, the upper part of the valley consists of dolerites and the ancient volcanic schists, but where Wadi el Gaetri enters Huluz there is a marked change in the character of the hills, those to the north having a different aspect and consisting of purple tinted schists traversed by bands of a very decomposed rock, apparently of granulitic nature. In the bend the southern series appears in bedded form dipping southward, the green phyllitic schists forming a harder well marked band.

At the next bend to the north coarse *hornblende-gneisses* come in strongly, also having an apparent southward dip of 60°, these being in their turn followed by a lighter *micaceous* variety much resembling a typical biotite-granite, except for the foliation. Dark bands are also occasionally present, and quartz veins are conspicuous, the latter sometimes having distinct copper staining. These types form the whole of the low country south of Wadi Hafafit, and are remarkably veined by pegmatite dykes, having a NE—SW trend.

Speaking generally, the country south of the Wadi Abu Had and Hafafit junction is *biotite-gneiss*, and to the north is a very dark close-grained variety penetrated by an immense number of pegmatite dykes which seam the rocks in all directions, smaller veins branching from them along the foliation planes. The red range north of Hafafit again differs, the rock composing it being a *red gneiss*, having strong affinities to a pegmatite. At the mouth of Wadi Nugrus a change takes place, the mica-and talc-schists of Sikait lying to the east, and the true gneiss of Wadi Gemal to the west.

Gneiss forms the prominent mountain range of Gebel Migif and probably also the main portion of the long straight range of Gebel Hafafit. Similar rocks have also been observed on the southern, and to a less extent on the northern side of Khrug.

The gneiss was subsequently traced down Wadi Gemal, where it assumes a hornblendic character and becomes almost a diorite-gneiss, while to the SE., in Wadi Um Sueh it became associated with

an acid variety whose characters suggest a granitic and intrusive origin. It, in fact, generally presents this duplicate dioritic and granitoid character. It was finally seen in its typical character near the gabbro region of Wadi Gau.

Lahami Gneiss.— In crossing over from El Ranga, on the Red Sea, to Abrak, a granitic country was traversed in the main, but in Wadi Lahami at a certain point there is a sharp change in the geology, the marked feature being the passage from the biotite-granite country seamed by basic dykes to one in which hornblende was conspicuous, the transition being accompanied by a very marked gneissose appearance. In the cliffs here, there is a complex due to an interpenetration of diorite-gneiss, hornblende-schist and an acid gneiss, probably each originally representing an igneous constituent. Here great purple dykes with boulder-like weathering became conspicuous, and from this point the main country rock was noted as diorite-gneiss. The gneissose character continued to the sharp southward bend of the Wadi, where the diorite-gneiss was restricted to the northern side, the southern hills being composed of closely foliated hornblende-schists with lighter acid bands, these in their turn being succeeded by a series in which a massive diorite was the predominant member.

Gneiss and Granite of Central Desert. — After crossing the watershed, gneiss appears locally in Wadi Khua, being penetrated by labradorite-diorite, granite, and syenite, but is soon replaced by diorite, etc.

Abu Beid—Abrak Gneiss.—In the neighbourhood of the Abu Beid well there is a conspicuous range in which the component rock is a *red gneiss* with intense foliation, while in the broad valleys east of Abrak there is an alternation of hornblende-and mica-gneisses, the general arrangement forcibly recalling the alternations of dark diorites and granites seen in the dyke country.

In the much-weathered country east of Abrak closely foliated gneisses and pegmatite veins form low ridges, and these rocks extend to the Nubian sandstone junction, the sandstone being faulted down against them.

The Allawi and Khrug Gneisses.—Gneisses are absent over a wide space south of Abrak, but reappear in the very dreary sand-strewn country just south of Gebel Romit, on the watershed between the Kharit and Alagi drainages. Here the gneisses are of varied character, dark grey

and light micaceous varieties alternating, penetrated by dykes of pegmatite and more basic rocks. For a time this is succeeded by an Aswan type of granite country, but on entering the Um Gholga drainage the gneisses again appear, though the actual Gebel Um Gholga is composed of a diorite. In this neighbourhood the Aswan type of boulder country again reappears for a short time, there being sometimes red granite and at others a mica-gneiss with NW. trending dolerite dykes. Gneisses, however, form the main rock on issuing into the Bijam plain. A minor gneissose region occurs near Zubara, Sukari, and Khrug, the Um Tundeba and Allawi hills being entirely gneissose. The type at Khrug occurs in some low hills to the north and south of that mountain and consists of hornblende-gneiss and schists traversed by red and dark felsitic dykes, trending roughly NE. and SW.

Granites, etc.—Up to the present we have dealt with rocks whose original characters are largely masked by foliation. There is, however, a wide series which in the main preserves its original structure, though it may become a gneiss under suitable conditions. The first large area occupied by these granites is situated between the Baramia schistose hills and Wadi Mia (the Marble Hill series), the rock itself being a biotite-granite weathering into boulders, but less conspicuous than the prominent NE. and SW. dykes which seam it. A second area is situated to the south of the Wadi Muelih and in the neighbourhood of the Sammut mines, again forming a conspicuous plain dotted with boulder-hills, the rock here being either biotite-granite or the Sammut hornblende-granite. This granite region extends west of Sufra up to the sandstone scarp, the biotite here being largely altered to chlorite. In addition there are places in this neighbourhood where the granite has undergone conditions of stress, gneissose structure being developed in it at several points, the foliated rock showing a well-defined arrangement along certain lines.

South of Sufra, the granite meets the schistose rocks, but the junction between them is not well marked. Circumstances prevented a very close study of the change, the most probable explanation of the appearance being that there had been interpenetration of the acid and basic member; from previous experience, the former would be more probably the intrusive member.

In moving south, granite was repeatedly met with south of Gebel Derrera giving rise to low boulder hills, mainly of biotite-granite, but with some hornblende in places, associated with dykes and veins of dolerite, felsite and quartz. There is, however, one type of granite

which plays so important a part in the hill structure that it cannot be omitted from consideration here, though really only a dyke on an enormous scale. This is the quartz-felspar granite which gives rise to a series of prominent hills, the principal of which is Hamret Mukbud. This isolated peak is one of the most conspicuous features in this portion of the desert, and rises abruptly from a plain dotted with low ridges of biotite-granite with porphyritic felspars, these being associated with dykes of pegmatite * (often showing a well-marked curvature) and dolerite. Gebel Hamret Mukbud is composed of a marked quartz-felspar red granite which appears to be limited to the mountain and the lower range immediately north of it. On entering the lower country to the east, one first meets with boulder-weathering biotite granite seamed by north trending dykes of pegmatite, followed in turn by a striking syenite dyke. Dolerites and schists for a time take the place of the granite near Wadi Abu Hamamid, but as we approach Gebel Tarbush Ahmar † there is a tongue of biotite-granite, while at Gebel Tarbush itself this rock partly traversed by red felsite dykes comes in strongly and forms the greater part of the Wadi Sheikh plain, which is surrounded by the dark hills of the older volcanic rocks. Gebel Tarbush itself is almost a quartz vein, an extremely quartzose pegmatite.

Further to the north, the bold peak of Gebel Abu Khrug is certainly in part a pegmatite of the same nature, and to the south the wild hills south of Owamtib (Shigig, etc.) are to be attributed to the same cause.

The pegmatite ranges are often characterised by their straight lined character, determining such marked features as some parallel spurs (now gneissose) of Gebel Hafafit and presumably of Gebel Ghorab.

Granite is by no means a conspicuous feature in the central watershed range from Migif to Abu Hamamid, though Gebel Nugrus is a conspicuous exception. There are, however, several examples on a smaller scale, the range immediately to the north of Sikait being of this nature, while in the Ambaut and Ghadir ranges the greater part of the hills are composed of a very light granite which forms a sharp contrast to the serpentines and schists which it penetrates.

The hills north-east of Sikait, in the neighbourhood of the Um Gamil mine, are of similar nature, while in Wadi Sikait, south of the mines,

* Where the term "pegmatite" is used, it is employed in the usual sense of a coarse quartz-felspar granite occurring in bosses or veins, and with or without distinctly marked graphic structure.

† The local name since given to Dr. Ball for this hill is El Hamra. On asking the guide the name of this hill, he replied that the one resembling a "tarbush ahmar" had no local name. This definition was adopted at the time for purposes of reference. W.F.H.

is a remarkable white boss of muscovite-granite containing abundant garnets, and penetrated by basic dykes, which form steps down the ravines. All these occurrences seem to be really examples of pegmatite veins on an unusually large scale.

A large area between Sikait and Hamata is formed of biotite granite, including the Gebel el Abiad, Shoab, Um el Abbas, Um Such, Abu Hegilig and the lower part of Um Heshenib, while further south the lower parts of Gebel Hamata are likewise of granite. Many of the hills on the plain of Selaia, such as Gebel Selaia and Gebel el Homur, are also of the same rock.

Except for prominent dykes of pegmatite, which are widely distributed in the lower gneissose country near the Red Sea, the unfoliated rock does not appear in bulk until Wadi Khalga (near El Ranga on the sea) is reached, where a very quartzose granite forms low hills in the course of the valley. South of the El Gulan mines there is a complete change in this respect, hornblende-granite first making its appearance to the west, and then on entering the Rod el Hashabab drainage the whole country is found to be composed of characteristic biotite-granite, traversed by felsitic and basic veins. Near Bir Amar, the granite coming in contact with the Bir Amar diorite gives rise to alternation of basic and acid gneiss, due to the intrusion of the acid into the more basic member.

On entering Wadi Lahami there is a passage from the biotite-granite to the diorite-gneiss country already referred to. Higher up Wadi Lahami there is considerable variation, the country-rock with granitoid weathering varying from a diorite through a hornblende-mica-granite to a biotite-granite. Quartz-diorites, mica-granites and hornblende-granites extend over the watershed into Wadi Khua. Granite again played a part in the country extending towards Abrak, sometimes being associated with gneiss and syenite, or replacing and underlying the spotted diorites. Between Abu Beid and Abrak gneiss alone was the important member.

Between Bir Shadli and Abrak, the plains are in most cases due to the wearing down of such granite areas, the most conspicuous of these being the El Selaia plain, out of which rises the isolated granite hill of El Selaia forming a conspicuous object in the landscape for many kilometres with its smooth round-topped summit. The granite of this plain where studied, evidently contains pink felspars, these forming an important constituent of the plain gravels.

The plain south of Wadi Kharit is composed of grey boulder-forming granite, with much epidote in places. Large hummocks of a very basic dolerite* also fringe and enter the plain. This rock extends

* More probably a contact rock (see p. 48).

towards the Qolaib sandstone escarpment on the west, while to the east its boundary has not been fully traced. On the western side scattered outliers of sandstone lie upon it, while quartz veins forming narrow and jagged ridges are also frequently present.

To the SE. of El Selaia plain, quartz bosses attain a large size, three brilliantly white low hills of this mineral being conspicuous features at the upper end of Wadi Elemikan. Further east, several hills of basic character rise through the granite. This plain is bounded to the south by the Um Harba sandstone ranges.

South of Abrak.—The road between Abrak and Abu Saafa is mainly in well-marked ravines bounded by sandstone walls, but at about 25 kilometres westward of the Abu Saafa well, hills of bold outline with irregular summits are seen rising in front, having at their foot a broad plain separating them from the sandstone. These are the Um Reit hills, the rock composing them being in the main a *granite* varying from red to grey. This is locally the eastern edge of a very wide granitic region whose boundary may extend south-eastward, but which certainly gives rise to the broad plains which are one of the marked features of the watershed at the head of Wadi Um Reit, and constitute one of the most desolate spots in an already desolate region. In front to the SW. rise some marked outlying hills, which gain in effect owing to the mirage which is probably a very frequent feature. Some of the dunes, with beautiful semi-circular curves, are striking objects at the foot of these hills.

South of the Gebel Shigig plain extends a granite country consisting of low hills which end in the abrupt range of Hamret Feg. On the other side of this range is a wind-swept waste of low hills with sand banked up against their slopes, some of the dunes having beautifully marked curved crests.

South of Wadi Abu Raitit, gneiss becomes the principal member, but there are several isolated areas of granite, giving the typical Aswan boulder scenery (see map), the most conspicuous occurrence being that of Gebel Um Gholga whose summit consists of boulders of huge size piled one upon the other.

Further south, the Ribdab hills are composed of a very striking granite with large porphyritic felspars which has been intruded into the metamorphics, and are surrounded by an aureole of schists showing interesting curvatures and dips which clearly indicate the effects of the granite upon them.

North of Wadi Murra is another west-trending range, Gebel Um Dubba, which appears to vary in its composition from a diorite to a rock of more acid composition, while in other places the rock shows foliation. There is a similar range to the south which was not visited.

The precise distribution of granite in the whole of this district is very difficult to follow owing to its frequent appearance in isolated patches. It underlies rocks of the most varied constitution, but large plains with boulder-ridges are an almost certain indication of its presence (except where a coarse granitoid gneiss takes its place).

North of Haimur and east of Um Tenedba is a plain with step-pyramid hills of diorite.

South-west of Haimur again is an expanse occupied by a typical granite with pink felsites and veined by a grey variety. South of Wadi Haimur, near Block E, another granitic area is conspicuous, the component rock being a mica-granite with occasional gneissose structure.

Returning to Wadi Murra, Abu Brush is a hill range mainly composed of the pink felspar granite, while to the southward of it, in the direction of Wadi Seiga, extends a series of diorites.

Still further south (according to Charteris Stewart) between Wadi Rodelbi and the Muqsim schists range is a broken plain composed of a granite much traversed by coarse pegmatite veins, while south of the Muqsim schists range is another wide granite plain extending into the Sudan. The eastern part of it, together with Gebel Um Tor, is formed by the quartz-felspar granite without ferro-magnesian silicates. East of Gebel Abu Dom are numbers of parallel dykes of possibly tourmaline-granite.

Perhaps the most interesting case of all is an island of diorite at Denabt el Qolaib, completely bounded by schists, some of which exhibit the Baramia-rock type of weathering. An area of a similar rock is also present between it and Um Araka and both localities are almost due north of Um Garaiart. On each side of these particular occurrences, the bands of calcareous schists have become more completely marmorized.

In the neighbourhood of Gebel Zerga, and extending to the edge of the sandstone, is a plain with the most fantastically weathered granite boulders (see page III.), the rock in part being traversed by basalt dykes.

Such, in brief outline, are the principal occurrences of granite in this portion of the desert, though in the main the granite varies from a highly quartzose to a grey more basic variety, and shows certain well-marked structures in various localities. Principal among these is

a well-defined graphic granite which occurs near Gebel Ribdab as a type locality, but is widely distributed having been also noted at Gebel Zerga. It occurs in all cases as parts of igneous intrusions. At Ribdab it generally follows the bedding of the schists, but occasionally cuts across them, in this respect agreeing with the quartz veins which are closely associated with them.

It has been remarked (Rastall, Buttermere and Ennerdale Granophyre, Q.J.G.S., Vol. XII, N° 246, p. 270) that in the laccolites there the graphic structure begins to appear a shor. distance from the margin, and as we approach the centre this intergrowth becomes continuously finer in texture, and of an increasingly perfect micropegmatitic structure. At Ribdab, however, the rock is not a laccolite, but a vein, and the graphic structure, which is very coarse, extends throughout its breadth. The closer grained varieties require further study.

Basic Fringes to the Acid Rocks.—A point of some interest is the frequent appearance of very basic dark rocks round the edges of the granitic areas, and between them and the schists. I am indebted to M. J. Couyat for having called my attention to the fact that similar rocks in the Eastern Desert are the hornfels or cornéennes which belong to the metamorphic aureole of the sedimentary rocks formed at their contact with the eruption rock.

DIORITES, &c.

Of a different order are the Diorites, Syenites, etc., which unfortunately are sometimes not sharply demarcated from the granites, but in the districts where they have been carefully studied show very definite relations to the latter, and are of great importance from an economic standpoint.

It is now well known that the minerals of a rock do not crystallise simultaneously, but often succeed each other according to the order of their basicity. It is therefore obvious that the heavier minerals will, by theory, as a rule be formed in the region of first cooling, which is the edge of the igneous magma, and it will be in that region that the quartz veins are most likely to obtain the metallic materials held in them. Observation has shown that these conditions are well exemplified in Egypt. Already, in 1902, the writer had called attention to the

Abu Khrug, and again in the dark hills which fringe the northern edge of Hamret Mukbud. It will be especially important to test whether these rocks are invariably present at the boundary of the granitic masses, thus representing extrusions along the edge of two rocks of different composition and aspect. A remarkably hard and fresh coarse dolerite or diabase forms the conspicuous cone of Gebel Atut, and the same rock occurs at Madaret Um Gamil. In both cases the lower slopes of the hill are covered with rusty brown rounded blocks, while above the masses are sharply angular. The weathering even in the most marked cases has only gone on to a very slight depth, the rock being perfectly fresh a few millimetres below. The rock of Atut rings like a bell under the hammer.

C. The third type of *Dolerite* or *Basalt* is of the widest distribution and has repeatedly been referred to in considering the Volcanic Schists, where its characters and occurrence are specially described.

DYKE ROCKS.

Typical felsite dyke country occurs to the north of Baramia, and throughout the region studied dykes are widely distributed. They have been already mentioned in previous pages, and to deal with them again in detail is unnecessary.

More massive occurrences of quartz-felsite occur at Igli and Hamata. A large portion of Gebel Igli consists of a very hard black felsite with white spots, associated with hornfels and schistose rocks. The summit of Hamata consists of a black felsite with remarkably clear glassy quartz; associated with it are dark schistose rocks and a beautiful green breccia; the base of the mass is granite.

MINES.

Old Workings and Their Significance.—Old workings are extremely abundant in the eastern portion of the desert, and in one or two cases have been the object of considerable development.

Baramia. The first case to be recorded is the Baramia Mine, which belongs to the second division above-mentioned. The country rock consists of

several dykes more or less parallel with the vein ; the nearest one (36 metres to the west) is of syenite. Both massive and crystalline quartz, also a coarse vein-breccia of quartz, with some calcite, were seen on the dump. The shafts are said to have been sunk to rather over 60 metres. At times, in places where the quartz vein died out on following a stringer of calcite, the quartz would reappear. There are also some less known workings which have been tried by the present Syndicate 3 kilometres NNW. of Sammut well.

Hamish.

Hamish Mine is situated in the Wadi of the same name 11 kilometres above its junction with Wadi Shait. It is situated in a syenite country, the strike of the vein being 15° to 20° E. of N. (magnetic) and underlying to the west. There are apparently three main shafts and some subsidiary ones, but as the levels from the shafts are under water, they could not be visited.*

Hangalia.

Hangalia mine is at the north end of Gebel Nugrus. A little east of the mine are numerous ruins, the site of a former mining town, with a well ; the well has been recently deepened, but has yielded only a little water, supplies of which have to be obtained from the pools of Migif and elsewhere. The country rocks are granite and schists.

Another group of mines is present in the hills to the north and east of Zubara, and several of these have been visited.

Allawi.

The first to be noted occurred in a small valley at the northern foot of Gebel Allawi (see map) in which were very numerous surface alluvial workings. An examination of these showed them to contain fragments of a grey-tinted diorite which was not present in situ. The base of the hill consists of graphitic and more nondescript schists as well as Baramia rock, and the whole is traversed by dykes. The diorite fragments were used as a guide and by their means some workings were found in the diorite itself which forms the western face of the range, the upper part of which consisted of schists penetrated by dolerites.

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* This mine is of particular interest owing to the extremely basic nature of the ore in places, the more remarkable owing to the acid nature of the rock. J.W.

It is noticeable that with the disappearance of the schists there is a corresponding absence of workings, none having been recorded whilst the writer traversed the granite region north of Wadi Lahami, the gneissose country east of Abrak, or the granite and sandstone country between Abrak and Haimur. One exception may be mentioned, a small working near Um Bsilla, which is of interest in that the country rock was again the characteristic spotted diorite. Workings are also stated to exist in Gebel Daha, a conspicuous range lying to the south-east.*

It was particularly interesting to find on reaching Wadi Murra that the typical diorite reappeared simultaneously with the schists, this valley being at the same time the northern boundary of an area which has formed an important centre of mining enterprise.

Mr. Stewart reports:— "In the immediate neighbourhood of the Murra well, to the west of Abu Brush, the whole of the small valleys in the schists are full of alluvial workings, there also being a mine in this neighbourhood. Further east I visited the Seiga mine (see Plate III), which is also situated in the schists, having a strike of N. 19 W., the dip being nearly vertical, but probably with slight inclination to the east. There is a large ancient working on the outcrop which must be about 12 metres deep by 6 metres wide. The working is largest at the junction of several small veins which have a strike between N. and N. 25° W. (i.e., cutting at very acute angles), and underlies a little to the east. The large part of the vein which traverses the upper portion of the hill (upon which the mine cairn is built) does not appear to have been a gold producer, as it is untouched. Four shafts have been sunk by the late Company (possibly a fifth by them also), and they have carried out a good deal of cross-trenching to search for outcrops. The shaft sunk in the widest part of the old workings is down some 9 metres, but very little driving has been done north and south at the bottom of the shaft. In the second shaft from the south, more driving N. and S. has been done. Two adits have been driven into the hills but abandoned without driving N. and S. There was probably an enrichment at the junction of the veins, which accounts for the ancient activity."

Leaving Absiel mine to be dealt with under the notes about copper, the great mines of Um Garaiart may be briefly referred to, though full detailed descriptions are to be found in the reports of the Nile Valley Company.

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* There are considerable ancient workings at Betaan and Um Eleagha, as well as others now being prospected.— J.W.

IV. The South Central embraces the region enclosed between the Central Watershed, latitude 25° N. (roughly) and Wadi Lahami, forming Mr. Streeter's concession in large part, and, in addition to the gold workings above described, including the emerald region.

V. The South-Western region includes Um Garaiart, Seiga and the narrowing of the sandstone east of Alagi correspondingly widens the mining area.

VI. The South-Eastern area is of considerable interest, as it includes the Hegatt and Daraheib centres, as well as many others now being prospected. *

Copper.

The occurrence of copper as an Egyptian mineral is already well known both from Sinai and the Northern part of the Red Sea Hills (see its occurrence near Wadi Dara in the Eastern Desert Memoir). Additional evidence of its presence has been afforded by this year's work, copper stainings and also more definite copper minerals having been noted on several occasions. The first of these was observed by Mr. Stewart in Wadi Sibrit, where a specimen of blue carbonate was obtained in the down-wash.

In moving from Bir Shadli to Sikait, the writer was not aware how close he had been to the workings reported at Abu Hamamid, so these as yet remain unstudied, but further to the north, near the junction of Wadis Durunkat and Gemal, quartz veins are conspicuous, one of these having marked green staining which yielded a reaction for copper on analysis, the country-rock in this case being a coarse gneiss. Of more interest is an occurrence some distance to the east of this locality, which is somewhat hidden among low hills to the south of Wadi Gemal, in the neighbourhood of Wadi Tundeba. The country in this neighbourhood consists of an intimate admixture of a dioritic and granitoid gneiss, and in these, among the low hills, is a quartz vein, somewhat ill-defined in extension, but appearing to trend NNW. The green copper ore (malachite) is not carried throughout the vein, but occurs in small seams, accompanied by ferruginous gozzan in places, while in others the matrix is a pure friable quartz, the thickness being somewhat less than a metre.

* With the information now accumulating, it will soon be possible to classify the mineral belts on more satisfactory lines than in mere geographical divisions, such classifications depending on the geological structure, the petrological studies, and the application of general principles as regards Ore Genesis to this complicated question.

sing the hill in an east-west direction, the country-rock being serpentine. This proves to be very rich in a chromium mineral, presumably chromite, and the analysis shows 30·70 % Cr_2O_3. The record is of special interest, as a chromium mineral has not hitherto been recorded from Egypt. In section the chromite is seen to be much cracked, being cemented by a matrix of carbonate of magnesia, analysis shows only traces of calcium, but much magnesia. The following is Lucas's note on this occurrence:

" In addition to chromium the sample also contains iron, aluminium and magnesium compounds in fair amount, and traces of copper, titanium and calcium."

While dealing with iron ores, it may be mentioned that a vein of chalybite was also observed by Mr. Stewart to the west of Dungash, under a cairn situated on a sandstone scarp.

Lead.

It is evident from the reports so far to hand that the gypseous or limestone belt which borders the Red Sea in many places, over at least four degrees of latitude, is a possible source of galena. Traces of it have been recorded from Wadi Jasus, north of Qosseir, veins have been found in Gebel Rusas, south of Um Rus, and Mr. James of Sikait has also informed the Inspector General of Mines that he had obtained this ore at the bottom of an ancient mine at El Ranga on the Red Sea. Acting on this information, the writer paid a rapid visit to the locality, but found that none of the accessible mines contained this mineral. There is one, however, which has been filled in with stones by the Arabs, as it was the den of a particularly destructive hyena. From Mr. James's account of his examination here, in which he stated that his first visit had to be abandoned on account of a leopard being at the bottom—the animal being subsequently dislodged by exploding a charge of dynamite—there is little doubt that this is the opening in question, but the time at my disposal did not permit of my staying another day to clear the opening. The gypsum here, however, is in many places of a bright yellow colour, being thoroughly impregnated with *sulphur*, which has earned it the name of Gebel Kabrit.

Marble.

Marble of varying quality has been frequently recorded both from the Eastern Desert and the Sudan, but none of these attain to the

quality of the one occurring in a low hill (Gebel Atafla, or Rokham) to the north of Wadi Mia, which the writer, accompanied by Mr. Ferrar, had the opportunity of visiting with Johnson Pasha and the Inspector General of Mines. The following notes were made by us during the brief inspection:—

The marble occurs not far from the junction of the two rock formations, the schists and the granites. There is a change on approaching the marble hill, the neighbouring ridges to the north-east being composed of a diorite similar to that of Bir el Sidd on the Qena-Qosseir Road. The marble, which is of excellent quality, is somewhat peculiarly situated, being bounded on the south by a black dolerite dyke, while it is also veined by the same material, the black rock forming a sharp contrast to the brilliant white of the marble itself. Some very ornamental banded marbles are also present, being possibly due to contact effects with the basic rocks intruding into them. From previous experience, the writer would have expected the marble to be interbedded in a series of schists which are often highly calcareous. From observations made by Mr. Wells, who came to this spot by a road from the north, it would appear that schists are interbedded with limestones, this making the occurrence of the marble in no way exceptional.

Emerald.

Occurrence of Emerald.—The writer having visited Zubara, Sikait and Nugrus, and having examined both the present and the many ancient workings, it is possible to give some opinion as to the occurrence of the Emerald beds.

Zubara.—The structure in the upper part of the Zubara valley appears to be as follows: –The base rock is a well-marked gneiss which soon disappears, as it is carried down by a SE. dip of $7\frac{1}{2}°$. Immediately above it is a band of dark mica- and talc-schists which formed the lead for the old miners, who have practically left no emerald-bearing quartz in the workings visited. The rocks above these schists are partly a crushed yellow rock (probably originally a serpentine) and partly slaty varieties, the whole being capped by a hard band, splintering in massive slabs, and dipping on an average 28° towards the southern valley. There is distinct folding on both sides of the N. valley, but, speaking generally, the SE. dip is maintained and the apparent dips of some of the layers are from 40° to 50°, a granitoid gneiss of fine texture closing the series at the cemetery east of the mines. On the opposite (east) side of a

transverse valley is the serpentine schist series with a dip in the same direction as those previously mentioned. The succession from W. to E. is briefly :—(1) Granitoid gneiss. (2) Emerald-bearing mica- and talc-schists. (3) Black spotted tourmaline schists. (4) Fine grained gneissose and green schists. (5) Splintery grey schists, with steep, almost vertical, dip. (6) Dolerite alternating with schist.

The typical emerald schist of the district when microscopically examined is seen to consist essentially of quartz with irregular outlines, muscovite mica fraying and otherwise appearing under strain, and with it being associated highly refracting red-brown grains and irregular masses of rutile, often following the cleavage planes of the mica. The acid rock underneath shows equal evidence of intense pressure action, the quartz grains being in small angular and elongated grains interlocked together, with them being associated both orthoclase and plagioclase felspars. It is, therefore, a crushed aplite, or granite, without mica in places, while in others it is a thoroughly typical gneiss.

Tourmaline is very closely associated with the emerald schist, the crystals of this mineral being scattered through a ground-mass of radiating mica to form a tourmaline-mica-schist.

Sikait.—The Sikait mining area has been carefully studied in the past, and a good general description has been given by Donald A. Macalister.[1] The essential points of the relations of the emerald schists are those mentioned, viz., that they have a strike of N. 60° W., and are inclined at an angle of 45,° and overlie a well-marked gneiss on the south in Wadi Sikait, while on the Gebel Sikait side they are enclosed by a massive green serpentine, forming the bold ridges on the summit of the mountain.

An elaborate cross-section of Gebel Sikait is given by Macalister, and the writer has also attempted a section in ascending the hill from the front. The succession from the mining camp was as follows:—(1) Crushed Green schists (hornblendic). (2) Quartz vein dipping 52° into hill. (3) Schists thrown into a series of sharp curves. (4) Spotted, very decomposed garnet-bearing gneiss. (5) Close-bedded schists. (6) Reddish nondescript schists. (7) Rock of biotite-granite aspect. (8) Crushed schists. (9) Serpentine rock. (10) Slippery folded talcose schists. (11) Quartz Reef. (12) Dioritic schists. (13) Splintered schists and quartz reef. (14) Actinolite schist.

[1] "The Emerald Mines of Northern Etbai," Geographical Journal, vol. XVI, July-December, 1900, p. 537.

(15) Dark mica-schists. (16) Talc-schist. (17) Emerald mine marked A.F. 51, and a micaceous rock with red spots. A. 53 is in a Talcose Rock type. (18) Small vein of Tourmaline rock. (19) A small vein of mica-schist separated the Tourmaline vein from a plug of biotite-granite. (20) Shiny mica-schists. (21) Mica-diorite (massive). (22) Green schists. (23) Talc-schist. (24) *Dark emerald-bearing schists.* A.F. 60 in opposite wall. (25) Talc-schists. (26) Basic schist. (27) Hard Talc-schist. (28) Vein of actinolite schist. (29) Green schists and serpentine veins. (30) Black massive serpentine. (31) Closely foliated schists and quartz reef. (32) Granite vein. (33) Massive serpentine. (34) Large quartz reef. (35) Mica schist. (36) Dark mica-schist with workings. (37) Fine-grained diorite and quartz in schists. (38) Broken grey serpentine with talcose films.

On the descent down the eastern spur fine specimens of the tourmaline rock were obtained in a gully near an old building on the hill.

From the above remarks it will be seen that the emerald-bearing schists are four times repeated in the hill side, in this respect differing from the other localities observed. Certain facts noted on the hill slope have led the writer to favour the view that this reappearance is not due to a series of beds, but to sharp folding bringing the beds to the surface four times in succession, but the settling of this point would require more time than was at his disposal. Further, the tourmaline and actinolite-schists seem to be very closely associated with the emerald-schists in many cases, though the section given above does not bring out the relation so strongly as is the case in some other exposures.

Speaking generally, the succession from below is therefore :—

1. *Gneiss* of massive character, probably representing an igneous intrusion which has been subjected to metamorphism on a regional scale.
2. *The Emerald-bearing Mica- and Talc-Schists*, associated with Tourmaline and Actinolite rock.
3. Massive serpentine.

Proofs of Folding in this region.—A particularly instructive example of complicated disturbance is seen in a dark hill to the north of the Sabahia Station (near Kurdeman), where schists and labradorite-andesite have been twisted and splintered in a remarkable manner. Further south near the Lewewi range, there is a well-marked flexure brought out by the hard beds in the series, the fold apparently having been also broken.

The possibility of repeated flexure at Sikait is further illustrated in the side of Gebel Sikait itself, where a Ushaped flexure of a quartz reef was very clearly marked in one of the valleys descending from that hill.

The Sikait mine opened up by Mr. James was at the time of our visit in a hard grey rock on the east side of Wadi Sikait, gneiss hills forming the opposite flank. The shaft was 26.5 metres deep, and a level had been driven from it to cut one of the quartz veins of an ancient working. Cross-cutting the level were soft mica-schists containing calcite nodules, while in the rock above followed by the old miners these nodules were of quartz, and some contained emerald. The existence of graphitic partings in the mine is worth noting.

In addition to those workings previously visited, several of the old workings were inspected in the company of Mr. James, the conclusion which was arrived at being in all cases the same, viz., that the miners had used the glittering dark mica schists or soft talc-schists as their lead, and had followed this up, leaving strong pillars of the material to support the rock roof. Indeed, in this department of the work, they could take few lessons from the modern miner, but wonder is felt as to what methods were employed in removing the material excavated from the mine.

Nugrus.—At some workings on a hill slope in Wadi Nugrus the close relationship of the emerald workings to the dark mica-schists was again exemplified, emeralds of poor quality being obtained from quartz lenticles contained in them. The presence of the gneiss was not specially noted, although some of the rocks in the valley near by were much foliated.

Um Kabu.—A brief visit to this spot showed that the emerald matrix was again a dark mica-schist. At the end of this valley in a small rock amphitheatre, is a very extensive ancient well (now filled up) and in the side valley near by are ruined buildings and some small workings, but the main scene of operation lies in the hills further to the east, and appeared to be of an extensive character.

It may be therefore generally stated that the *emeralds* appear to be restricted to a *dark mica-schist* or *talc-schist* zone immediately overlying a well-marked *gneiss*, and to be mainly obtained in *quartz* lenticles occurring in the schists. Their presence at several levels in Gebel Sikait may possibly be due to repeated flexure of the softer schists crushed between the harder gneisses and serpentines bounding them.

Pyrites, Marcasite and their Products.

Two occurrences aroused some interest on account of their peculiar character, the first to which Mr. James called my attention being in the gneiss range on the south of Wadi Abu Rashid in one of the wild gullies which have deeply scored the hill-side. Here a quartz vein has been coloured yellow by powdery sulphur and further examination showed it to carry a large amount of the easily decomposed sulphide of iron, marcasite. An analysis by Lucas also shows traces of copper, cobalt and zinc to be present, but no gold or uranium.

The other case occurred near Sebahia, where a striking mass of red rock borders the road. This contained very minute specks of a metallic substance, which proved, however, to be pyrites, from its silvery appearance probably in part arsenical.

A special visit was made to some old workings near Bir Ghashab in the dolerite hills north of Hamret Mukbud, there being remains of many buildings in a small valley opening into Wadi Ghashab. The doleritic boulders have been turned over, but without a more thorough examination than could be given at the time, the mystery of these workings will not be solved. The writer was anxious to visit some other mines of this nature reported near Gebel Nukheira, but the opportunity did not present itself for so doing.

Summary.

The general study thus leads us to conclude that:—

1. The quartz-veins carrying *Gold* in this region are generally either in the schists or in the dioritic or syenitic rocks closely associated with the schists. They are but rarely in the acid granites.

2. *Copper* in the form of carbonate, chloride, etc., is present in the gneisses and schists, and has been formerly worked at Absiel and Abu Hamamid.

3. *Iron Ore* occurs in the form of Titaniferous Hœmatite due to concentration of the ferruginous minerals in a Gabbro in Wadi Gau, near the sea north-east of Gebel Hamata.

4. *Sulphur* is present in the gypsum of El Ranga, on the sea near the above locality.

5. *Lead* Ore (Galena) has been recorded in the gypsum from the same spot.

6. *Emerald* (beryl) occurs in a mica-schist or talc-schist overlying gneiss in the Zubara—Sikait neighbourhood.

7. There are certain workings in dolerite whose object still requires determination.

8. *Marble* of good quality occurs in the upper part of Wadi Mia.

TECTONIC CHANGES.

In the absence of distinctly marked fossiliferous strata, the presence of faults is in many cases difficult to determine, especially as the Nubian sandstone shows very slight variations in texture. Nevertheless, there are evidences of fault-changes, and on these Ferrar reports as follows:—

"The bedding planes of the sandstone are usually horizontal, though small faults locally displace and tilt some of the beds. It is noteworthy that the east and west faults are more in the nature of joints which do not alter the dips of the beds, though occasionally these may be displaced or let down vertically, The north and south faults often cause the beds to dip at considerable angles, though the majority seem to have let the beds down vertically without any tilting. These faults occur along vertical planes, which cross each other roughly at right angles, and have broken up the plateau country into a series of crust blocks. These crust block mountains are more obvious than the rift valleys which accompany them. As an example of the former, we may mention the higher land on the longitude of Bir Abad which has been traced from here southwards to Wadi Shait as a chain of elevated plateaux. These plateaux are nearly 200 metres above the wadi beds, and 100 metres above the land to the east or to the west, and form a mountain wall roughly parallel to the Nile Valley."

" East of this chain lies the 'trench' already referred to, and the variable dip of the sandstone, which is both to the east and to the west, but not often over 5°, is worth recording. Attention may be called to certain well-marked fault-effects, notably in Wadi Beza, near the Rod Abu Nugara depression where horizontal sandstones

are in contact with sandstone beds dipping 10° to the west, while the faulting at Gebel Nugrus has already been mentioned."

This evidence of faulting in the interior of the sandstone country is interesting, but stands by no means as an isolated example.

Abrak fault.—A notable fault occurs where the sandstone and older metamorphics are in contact at Abrak well and in the escarpment to the south-east of that well. Immediately above the second Abrak well (near the fort) the fault in the hill-slope is seen to be reversed, the dip being steeply towards the valley in which the water appears, whereas to the north as shown in a photograph by Stewart, the reverse is the case, the sandstone strata being bent up instead of down. This fault has probably determined the fault-line which extends far to the south-east.

The importance of folding has also been mentioned in speaking of the emerald mines, but it is, of course, difficult to determine the significance of the features in a country entirely composed of igneous and metamorphic rocks.

SUMMARY.

As a result of this season's work in the Eastern Desert, we may therefore mention the following special results:—

1. The triangulation of a central area from lat. 22° to 25° N.
2. The triangulation of an eastern area from lat. 24° to 25° N.
3. The fixing in more accurate position of the principal hills, wells, roads and mines in this region, and the determination of the altitudes of some of the more important summits in the Central Chain.

From the more strictly geological standpoint, the following results are the most striking:—

4. The southern extension of the known Eocene beds.
5. The proof of the wide extension of Cretaceous beds as plateau-formers east of the Nile between Edfu and Kom-Ombo.
6. The significance of faulting in the sandstone region.
7. The presence of fossiliferous strata in the centre of the desert at Abu Harba.
8. The record of a new fauna associated with carbonaceous shales in the Mines Department well at Abu Rahal.
9. The evidence of volcanic activity during the deposition of the Nubian sandstone.

10. Faulting at the eastern edge of the Nubian sandstone (Abrak).

11. Outliers showing forming extension of sandstone probably over the whole desert, and even on to the shore at El Ranga.

12. If the gypsum represents altered limestones, these latter are also present at El Ranga.

13. Recognition of the main types of metamorphic rocks (Gneisses, Schists, etc.), their distribution and characteristics.

14. Further notes as to the method of occurrence of Gold, Copper and other minerals.

15. Existence of Hœmatite and Sulphur near El Ranga.

16. Description of the mode of occurrence of Emerald.

17. Brief note of the occurrence of Marble and other minerals.

18. First record of Chromite in the Eastern Desert.

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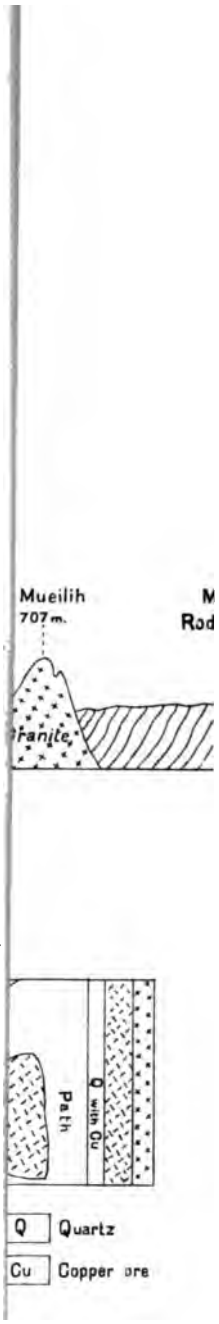

Plan of Copper ore

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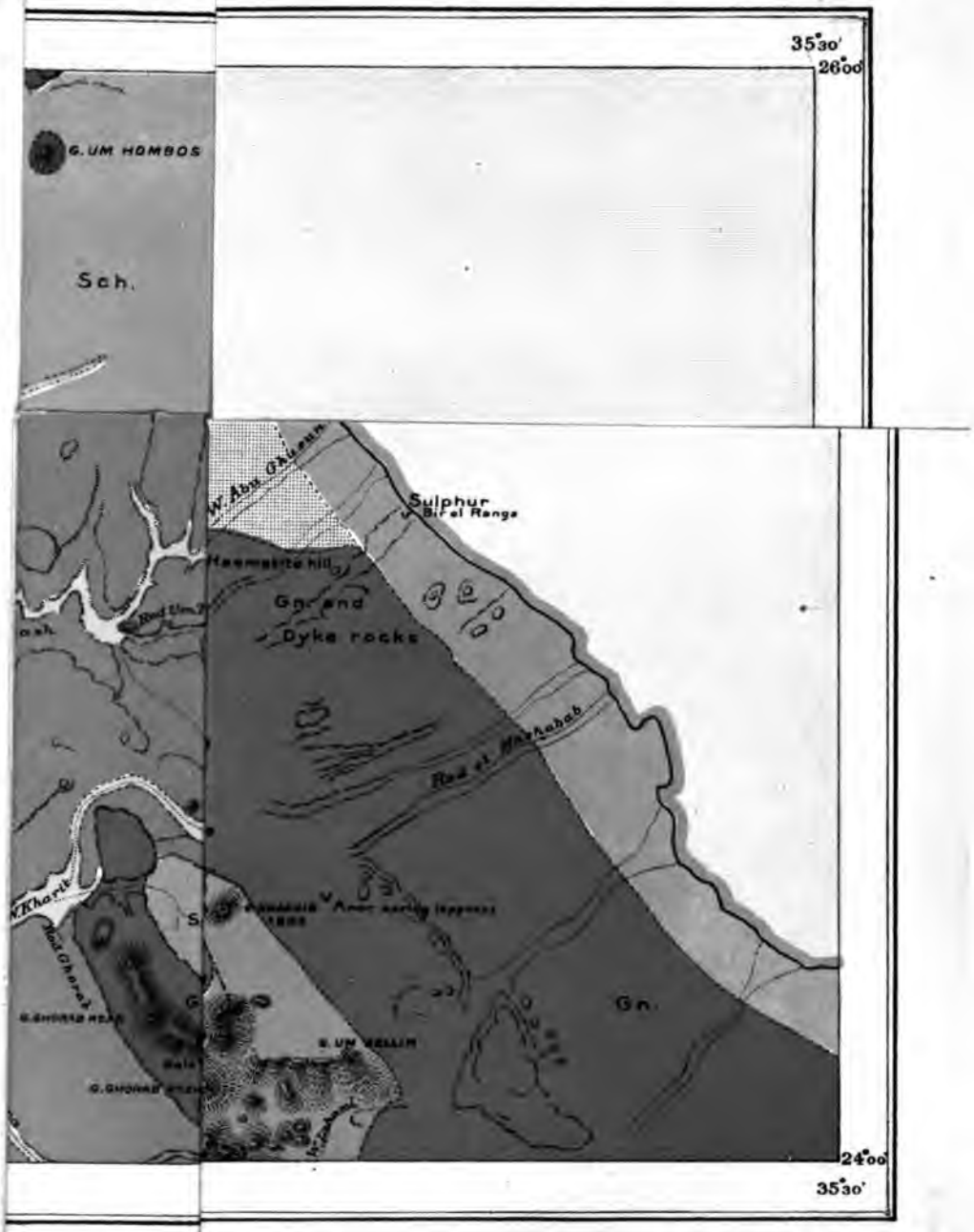

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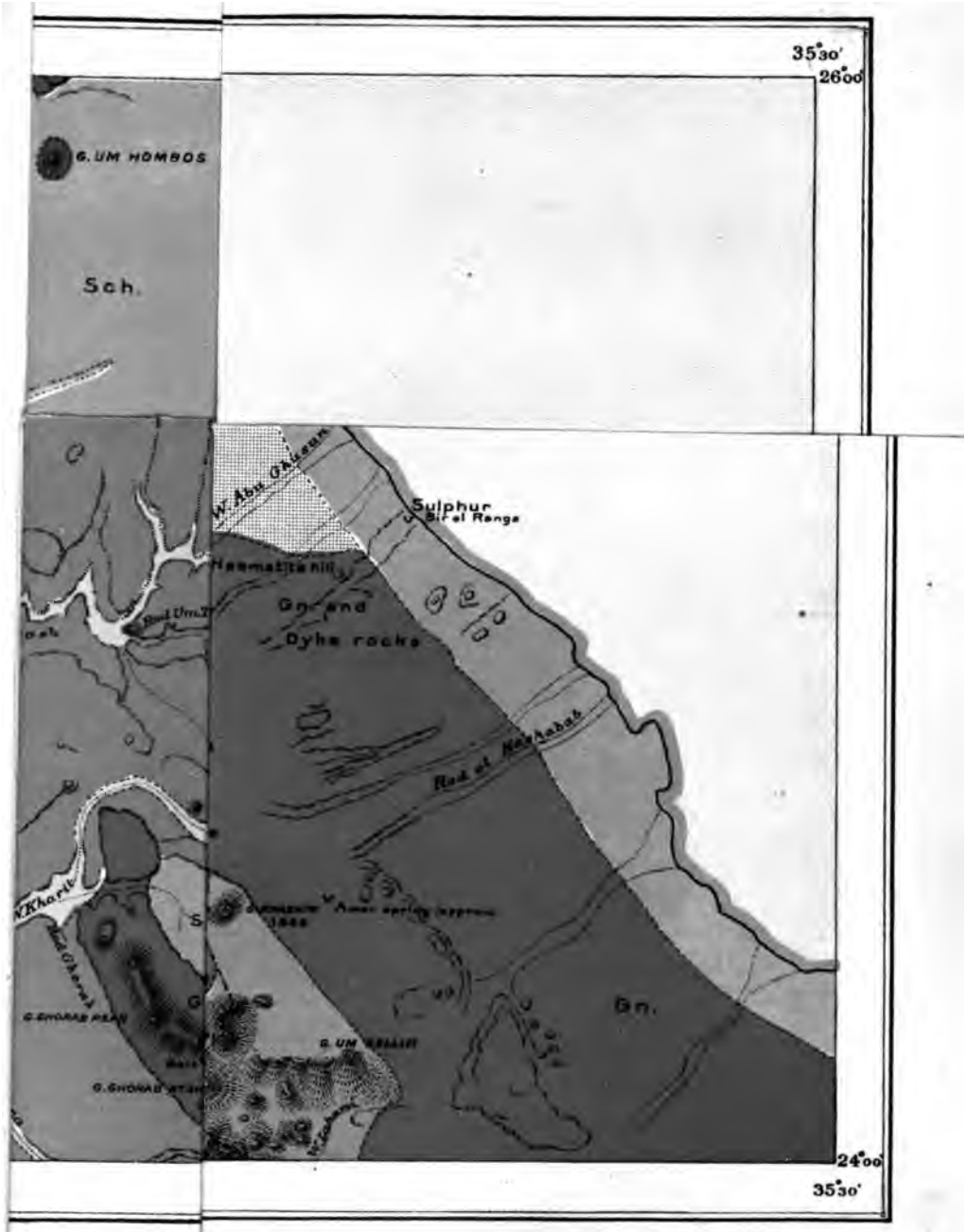

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